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Risk Management in the Development of Drilling Technological Projects

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Abstract
Recovery of hydrocarbon is an important aspect of the O&G industry, which has gained much importance in recent times. It can be achieved through a set of activities and decisions in which successfully drilling the oil/gas deposits is very important. Drilling is a critical step in the exploration process, and it has a high level of risk in terms of cost, timeline, safety, and project completion. The study focuses on identifying, evaluating and estimating unforeseen events that may occur during the drilling projects. The methodology acquired for this paper includes a thorough focus on the literature review which has been done. It consists of a model/theory related to risk management and the concept of risk management processes. A comprehensive project life cycle model with six stages has correlated with the drilling phases. Detailed risk management has been practised for an integrated risk portfolio for the development project. A generalized risk identification approach has been utilized to recognize possible threats. A qualitative risk assessment has been executed for the findings. Impact and probability benchmarks are categorized per the past historical well's performances and published data. Considering the importance of risk management for said projects, the study focused on the literature review that highlights the processes, procedures, and models for drilling risk management. Risks have been recognized through a rigorous and comprehensive risk identification process and have been evaluated with the qualitative risk assessment approach. The risk register for development drilling projects has been developed along with the risk matrix as per the defined criteria of risk impact and probability for drilling. Furthermore, a detailed risk breakdown structure has been formulated according to the general area categorization to enlighten the risks focused on each area of interest. Overall, the study will provide a value-added and detailed risk management approach for new ventures, which may be planned with the implementation of comprehensive drilling risks management.

Keywords
Integrated Risk Management, Energy Security, Drilling risk indicators, Risk Impact Matrix (RIM), Petroleum exploration and production.

Introduction

Energy is critical to the growth of nations and societies. Global energy demand is predicted to skyrocket over the next few decades. This is mostly owing to the predicted increase in the global population and developing countries' economic and industrial progress (Tufail et al., 2018; Hassan et al., 2019; Ayu et al., 2020; Nawawi et al., 2022). Coal, natural gas, and oil are the key contributors to meeting the energy demands of much of the world (BP statistics, 2014). In order to develop/exploit recoverable hydrocarbon reserves, Drilling and completion operations must be carried out with extensive and thorough operational planning. Both energy services and energy security are intertwined and critical to society's well-being. The risks associated with technology and operations must be realized when it comes to energy threats. Drilling is a critical step in the exploration process, and it has a high level of risk in terms of cost, timeline, and project completion (Yasseri, 2017). It is carried out to produce oil, gas, and condensation for energy generation. Drilling can also be used to prove the presence of resources, determine the extent and size of the reservoir, and validate the resource's long-term viability. The drilling environment plays a significant role in the drilling operation's risk (Bhandari, Khan and Garaniya, 2013). These risks have unfavourable consequences, including a negative impact on project completion, economic strength, professional status, and environmental sustainability. Drilling is a unique industry in that it involves almost entirely subsurface building. It is a specialist industry that necessitates the use of specialist equipment as well as highly trained workers. Although the procedures are identical worldwide, there are distinctions in how different types of wells are drilled depending on their purpose. Drilling may be a unique industry in that all development takes place in the subsurface for all intents and purposes. It is a specialist industry that necessitates specialized hardware and a highly skilled workforce. The procedures are identical all throughout the world. However, there are differences in how different types of wells are penetrated depending on their purpose. Drilling projects that are plagued by risks and uncertainties deviate from the critical path of planned drilling operations and create hazardous working circumstances, compromise the well's integrity, and drastically raise drilling costs. Drilling risks also have an impact on the project's schedule, as drilling time is spent on mitigation measures rather than well development, increasing the well's cost directly or indirectly. These risks are typically under-accounted for in project cost planning and control.

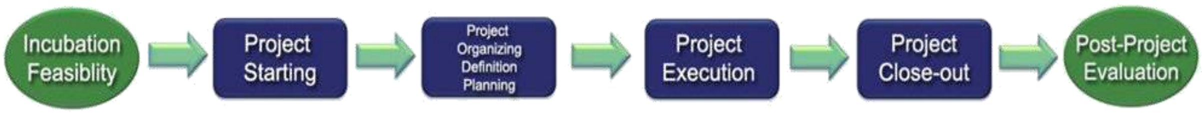


Fig. 1. cycle stages relate to drilling project(s)

In every drilling operation, the unsympathetic of the drilling project life series will serve as a foundation for risk detection, analysis, and evaluation. The project life cycle is a logical framework for looking at the nature and scope of project management decision-making. The project life cycle is a logical framework for assessing the nature and scope of conclusion-building in project management. Figure 1 shows the "comprehensive project life cycle model" with six stages, as Archibald et al. (2012) highlighted. Table 1 shows how project life cycle stages relate to drilling project(s).

Tab. 1. Comparison of Project Life Cycle in the Drilling Phase

Project Life-Cycle	Drilling phase
Incubation	Well designing
Project starting	Operational planning
Project definition and planning	Deployment/Mobilization
Project execution	Drilling operations
Project closeout	De-mobilization
Post project assessment	Documentation and Lesson learnt

Several studies in the past have discussed risk management planning in drilling projects (Bennett and Ariaratnam, 2008; Statter et al., 2007; Bayer, 2005). Donovan and Hanford (2012) have discussed the importance of adopting risk management planning in drilling development projects. He proposes some common suggestions for site investigation and design evaluation. Similarly, Krechowicz (2017) stresses the importance of proper risk planning in complex construction projects. Giereczak (2014) conducted risk identification and qualitative risk analysis in development drilling projects. He collected expert opinions from 5 different countries and proposed a comprehensive risk management process.

This paper's key objectives and goals are to identify the risks of development drilling projects through detailed analysis of literature, related projects professionals, and available lesson learned. Assign the probability of events based on the possibility of happening in the period of drilling along with impact(s) which may influence the overall project in terms of cost, schedule, technical risks, health and safety, and environmental and organizational reputation. Furthermore, a qualitative risk assessment is to be implemented, considering the cost as a key impactful factor and analyzing the general risk standings which are related to development drilling projects through an integrated risk matrix. The paper will also highlight the key domains/areas of risk(s) which can delay the project delivery and compromise the quality of deliverables.

Literature

Risk management involves dealing with risks logically, intending to escalate the likelihood and impact of constructive events while reducing those of undesirable events (PMBOK, 2013). Wideman (1992) outlines project risk management as "the art and science of identifying, assessing and responding to project risk throughout the life cycle of a project and in the best interests of its objectives." For the persistence of this research, the characterization of risk management used in Risk management: Principles and strategies (AS/NZS ISO - 31000:2009). It comprises five mechanisms of the risk management processes that must be accomplished (as shown in Figure 1).

1. Communication and consultation.
2. Establishing the risk context
3. Risk assessment
4. Risk treatment
5. Monitoring and review

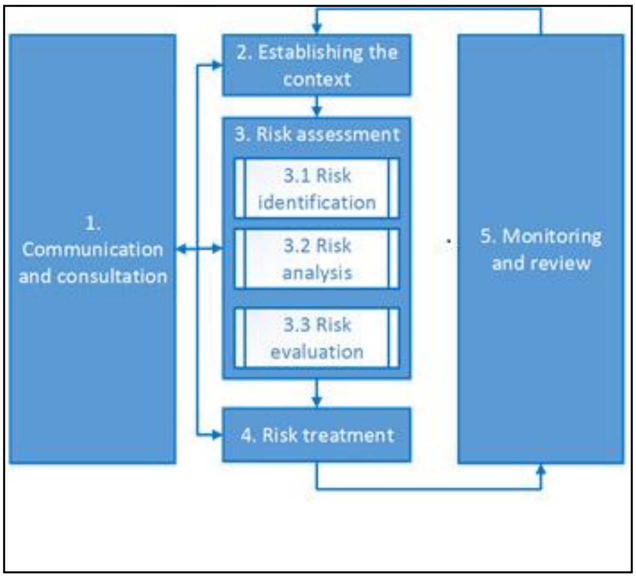


Fig. 2. Risk management method (Standards Australia, 2009)

The risk management process comprises communication and discussion to determine who will be involved in each risk management process element. This procedure also allows the parties involved to keep up to date on the process's progress and issues. Effective risk management demands the definition of a scope boundary as well as risk benchmarks, besides which the risks will be evaluated. To establish the context, one needs to define the following:

I. The internal context - refers to the organization's internal environment, which comprises internal stakeholders, domination approaches, contractual relationships and competencies, culture, and standards.
II. On the other hand, the external context is the atmosphere in which the organization operates and has little influence over it. External stakeholders, the organization's local, national, and worldwide regulatory contexts, and market circumstances are examples of these.

Risk Assessment

The process of risk assessment consists of three altered phases, Identification, analysis, and evaluation (Standards Australia, 2009; Ennouri, 2015). The two dimensions, estimation and evaluation of risk, were identified by Otway (1973); in continuation, Kates (1978) added the third process of risk identification. The three dimensions are concise and concrete because of three reasons. 1. Identification of the risk is the most important step in risk assessment. The problem can never be resolved unless it is identified. It includes the overall understanding of the process, Identification of negative and possible events that may occur and jeopardize the core objective of project 2. The risk assessment process includes the removal of uncertainty even via the process of deduction, revelation, intuition, and extrapolation. 3. The risk evaluation process is used to compare estimated risk with the risk assessment criteria. It helps to minimize the risk threshold and manage the risk appetite. Techniques like CBA (Cost- Benefit Analysis), decision tree Monte Carlo analysis etc., may be employed to manage the risk (Tufail et al., 2018a).

The treatment of risks entails making judgments on in what way key potential risks will be dealt with. Multiple stages of risk are analyzed during evaluation, and risk handling selects suitable resolutions for management. Unacceptably high hazards will necessitate rapid mitigating measures. Risks which are adequately small and are measured of negligible consequence on activities may be reserved (Scarlett et al., 2011; Tufail et al., 2018). Most collective approaches for risk countering are:

i. Avoidance-Approach to eliminate the risk
ii. Reduce (mitigate)-Developing a plan to reduce the consequences or the likelihood of a risk.
iii. Transfer (share)-Moving a risk else ware (to the supplier, to an insurer)
iv. Retain (accept)-Allow the risk to remain and deal with the consequences.

To ensure that the risk management processes are effective and to detect any novel risks arising from either the mitigations or the alteration of the project atmosphere, it must be monitored and reviewed regularly. Known risks can be traced, and the risk which has been closed can be eradicated from risk evaluation (PMBOK, 2013). One tool which has been utilized in the industry for risk mentioning, monitoring and analysis is a risk register.

Following are the fundamental recommendations which have been proposed as Rules for drilling risks management (Rongchao Cheng et al., 2013):

- Improvisation in offshore technologies being used in the drilling process.
- Supplementary revisions in drilling specifications, standards, and regulations.
- Establishment of a special organization accountable for offshore safety supervision and management.
- Buildup HSE system for deep water.
- Allied system foundation in case of blowout emergencies, oil spills and fire explosions.
- Introduce advanced training, talents and improved deepwater technologies.

Workflow has been experimented on three onshore development wells to enhance drilling efficiency while managing and controlling the related risks. It also targeted reducing non-productive time (NPT) and hazard management. Workflow proved to be very effective and provided successful outcomes with lower investment in recognized technologies, capitalizing on an effective workflow and collaboration of diversified skillsets and experiences. Below are colour-coded workflow elements proposed and experienced by (Elena Cantarelli et al., 2017) (Figure 3).

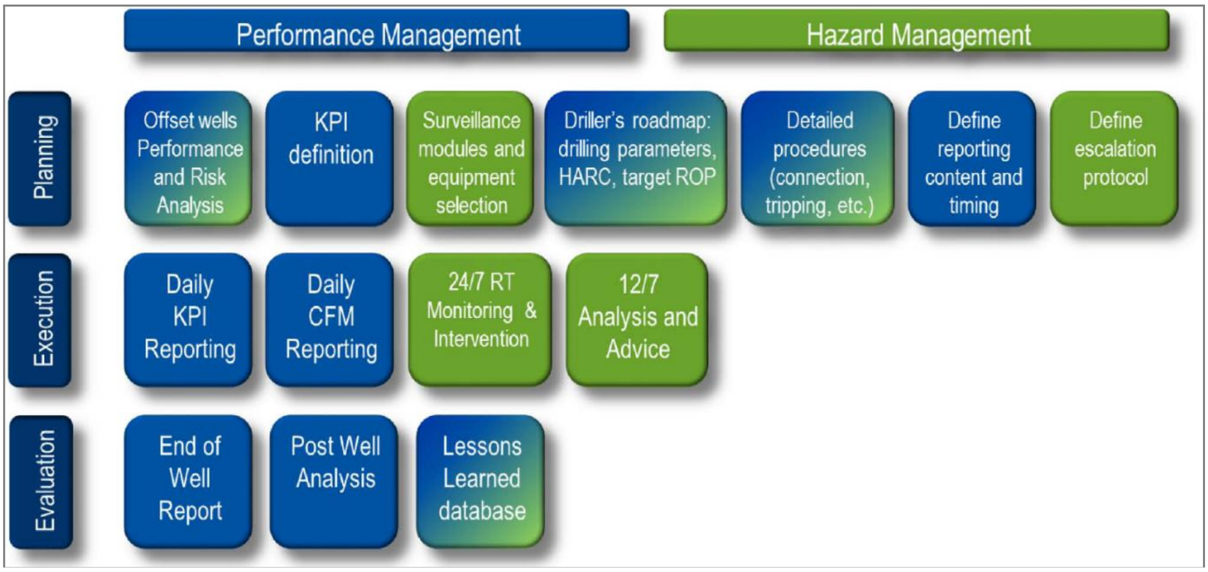


Fig. 3. Colour-coded workflow elements

Drilling process risk management

Drilling risks could lead to project delays, cost overruns, temporary or permanent well abandonment, income loss, physical destruction to equipment, harm to personnel, reputation, and business loss, among other things.

Technical risks: Technical risks account for most risks associated with drilling projects. They are frequently associated with geological formations, as well as the supply and delivery of equipment and materials. The challenges that arise during production are not discussed in detail in this thesis. These risks were more alienated into 6 classes that are labelled below:

i. Geophysical & Geological
ii. Drilling materials and consumables
iii. Force majeure
iv. Casing and cementing
v. Well success

Geological risks: Hydrocarbons are found in complicated geological formations, which explains why drilling encounters many formation problems. Risks which may arise due to the subsurface geological behaviour are defined below:

i. Drilling Mud Loss
ii. Stuck pipe
iii. Hard and soft formation
iv. Wellbore instability- collapsing formation
v. Magma/intrusions in wells (deep wells).
vi. High pressures and temperatures

Casing and cementing: Subsurface drilling necessitates the use of cement and casing. Long after the rig has moved, the effects of inadequate cementing and casing might be felt. Due to casing collapse, these results could render a well unproductive, resulting in a loss of investment. A few problems pertaining to casing and cementing in this study are defined below:

i. Casing wear and tear
ii. Parted casing
iii. Cement Loss
iv. Casing off-set (decentralized)
v. Cold inflows- poor cementing
vi. Cement hardening inside the casing

Equipment challenges: Equipment used for drilling activities is quite expensive, and also the project components are subjected to the most difficult conditions. Protection of equipment through mandatory preventative maintenance and periodic integrity check should also be a priority. When equipment fails, it results in lost productive time due to repairs and the search for replacement parts. Key major tools failures observed are listed below:

i. Drilling pipe failures
ii. Loss of BHA, drilling tools, logging tools
iii. BOP failure
iv. Heavy-duty machine failure.

Drilling material: Drilling consumables and supplies are required for the drilling rig's everyday operations and drilling operations. Their supply should be scheduled for and supplied to the job site as needed to ensure that the project is not disrupted.

i. Long lead periods of material delivery
ii. Disappointment in assigning risks properly in the contract
iii. Bureaucracy in the tendering process
iv. Deprived materials quality

Force majeure: These are inescapable circumstances that cause the expected flow of events to be disrupted and participants to be unable to fulfil their duties. They include, for example:

i. Extreme-weather conditions
ii. Earthquakes
iii. Country insecurities / War.

Well success: Sveinbjörnsson (2014) describes effective wells as those whose capacity was available or estimated sufficient for linking to the power plant or intended operation, such as re-injection wells with good injectivity. Unexpected mechanical failures throughout drilling ensuing in partially filled or bridged wells, insufficient temperature and low/high reservoir pressures, intolerable chemical difficulties, low productivity index, and wells which do not influence the reservoir are among the reasons listed in the study.

i. Plugged and abandoned well
ii. Non-productive well:
iii. Suspended well - not completed:

Health, safety, and environmental Risks (HSE): Safety and environmental risks are those that have an impact on workers, property, and the operating environment. The well drilling sector has numerous dangers that have the potential to cause serious injury to people, nearby areas, and the atmosphere, making HSE a critical problem. Furthermore, if these dangers materialize, they may result in legal action and a tarnished business reputation. Many risk evaluation criteria and supervision in the drilling industry have serious attention to HSE risks, and extraordinary protocols have always been established for drilling-related activities. Eight risks were recognized and are defined below:

i. Toxic gases are released from the subsurface.
ii. Machinery noises.
iii. Leakage or failure of the brine pond
iv. Equipment safety
v. Working environment
vi. Air pollution
vii. Disposal of formation cuttings
viii. Chemical and Thermal pollution

Financial risk: The majority of financial risks in geothermal drilling stem from the length of the project and the risks associated with the drilling procedure. However, some can be credited to financiers. As a result, numerous drilling activities have cost escalations. Risks identified for this category are mentioned below:

i. Higher drilling cost
ii. Exchange rate and Interest rate fluctuation.
iii. A decline in annual budget provision by the government
iv. Low credibility of shareholders and lenders
v. Delay in Payments from stakeholders
vi. Bankruptcy of project partner
vii. Price instability of fuel and steel
viii. Changes in bank regulations and protocols

Legal risk: There are various legal risks associated with geothermal drilling. On the other hand, this thesis examines two dangers that may arise because of contract management.

i. Inappropriate authentication of contract documents
ii. Breach of agreement by project parties

Organization risk: In a continually changing environment, organizations confront a variety of risks. These risks have a broader impact, affecting not only the project at hand but also the entire establishment and extending beyond the drilling project's life cycle. Two categories were observed in this domain:

i. Management risk
ii. Human resources

Policy and political risk: Depending on the country, policies and politics dictate how geothermal drilling projects are carried out. They specify how project funding is collected and used, who is permitted to operate in the state/province (an overseas specialist crew occasionally does drilling), and how procurement is carried out. Risks pertaining to Policy and political risks are mentioned below:

i. Cost escalation due to variations in Government policies
ii. Low/inadequate budgetary allocation
iii. Loss incurred due to corruption and bribery
iv. Procurement policies (e.g. extended tendering process)
v. Damage due to late approvals

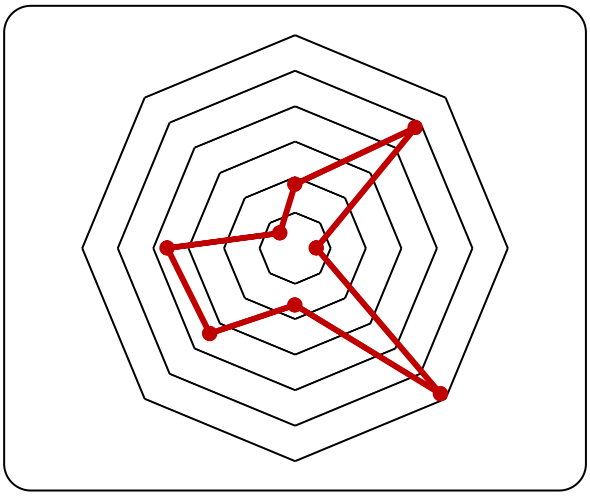
Methodology

The methodology acquired for this paper includes a thorough focus on the literature review which has been done. It consists of a model/theory related to the risk management concept of risk management processes. Drilling risks identified and presented were evaluated through a qualitative risk assessment process. Finally, an integrated risk matrix is simulated based on risk ratings with the help of the MS Excel tool.

Risk Identification: The process of identifying, classifying, and determining the significance of project risks is known as risk identification. Documentation review, information-gathering strategies (such as interviews and questionnaires), checklists, brainstorming, assumptions analysis, root cause analysis, SWOT analysis, and diagramming techniques are among the tools and practices included. The output of the risk identification route includes triggers, risk lists and inputs for other groups or processes.

Tab. 2. Risk Categorization and the number of risks identified

Category	No. of Risk
Contracts and Procurement	9
Finance & Economics	24
Force Majeure	3
HSE & Community & Security	29
Information and communications technology	8
Legal & Commercial	17
Operational	18
Policy and political risk	3
Total	**111**



Risk Analysis: Risk analysis examines the risks that have been discovered as well as their sources, determining their impact in relation to the likelihood of incidence and magnitude of impact on the plan. There are two approaches to risk analysis which are described below:

Qualitative risk assessment: Where numerical data is insufficient or unavailable, qualitative risk assessment methods employ a descriptive scale. Once risks have been discovered, qualitative approaches classify them into "low," "medium," and "high" categories depending on the probability of loss. Because qualitative risk assessment provides for the portrayal of risks and is a simple, time-saving form of risk assessment, it is more widely utilized than quantitative risk assessment because numerical values are not always readily available. Probability, also known as likelihood, expresses the risk's uncertainty by indicating whether a risk occurrence or condition is possible to arise on a scale ranging from impracticality to certainty. This range is defined differently depending on the projects and the risks being evaluated (Hillson and Hulett, 2004), as shown in Table 3. Probabilities assigned to a particular risk are based on the likelihood of an event over a period of the drilling process life. Table 3 below has been scaled for the probability distribution, which will be assigned to the identified risks:

Table 3: Probability Assessment Table

Probability %	**< 5%**	**5-10%**	**10-20%**	**20-40%**	**> 40%**
Category	**1**	**2**	**3**	**4**	**5**
Description	Very Unlikely Improbable May never occur	Unlikely Remote At least once in a well	Likely Occasional Marginally happen during the drilling of the well	Very Likely Probable Few times during the drilling of the well	Certain Frequent Multiple times during the drilling of the well

Impact provides the magnitude that the incidence of the event will have on the project (Hillson and Hulett, 2004). It defines the impacts or repercussions that will occur as a result of the occurrence of a risky event. The impact is commonly quantified in terms of cost or time waste, the status of the company, loss of business, personal injury, or property damage. The impact can be measured in terms of "High, Medium, Low" or numerical values (1 - 5). The tables below define the impact measures used in this study.

Risk Impact is assigned to a particular risk based on the cost associated with the event over the period of the drilling process life. Risks that appeared over the project period may bring adverse impacts on a variety of domains, such as cost/schedule/technical risks/ HSE risks/ environmental and organizational reputation. Table 4 below has been scaled for the risk impact/consequence each event may expose, which will be assigned to the identified risks:

Table 4: Impact Assessment Table

Risk Rating Consequences / Impacts							
Score	**Rating**	**Cost (USD)**	**Schedule**	**Technical Risks**	**HSE Risks**	**Environmental**	**Organizational Reputation**
5	Catastrophic	>5M + 25%	> 1 week	Loss of Well	Fatality	Massive Damage	International coverage
4	Critical/Major	>2M	> 24 Hours	Loss of more than 1 section	Permanent Disability	Extensive Damage	National Coverage
3	Serious	>250K	~ 24 Hours	Loss of 1 section	Disability for 3 months	Harm to the outside Environment	Local Media Coverage
2	Marginal	>50K	< 12 Hours > 24 Hours	Loss of < 50 Meter	Disability for less than 5 days	Temporary Harm to the outside Environment	Local Community complains
1	Negligible	<50K	~ 1 hour	Loss of > 50 Meter	Minor Injury	Minor Harm to the outside Environment	Internal Complain

Risk Matrix: A risk matrix is a straightforward graphical tool for ranking and prioritizing hazards. It usually has two axes: one for the chance of existence and the other for the impact. Different colours in the matrix represent the risk level. A 5x5 matrix was implemented in this paper, as shown in Table 5 below. Risk matrixes are commonly used in decision-making to determine how considerable risk is tolerable and which risks should be handled first.

Table 5: Risk Impact Matrix

Matrix			**Likelihood / Probability / Potential Frequency**				
			May never occur	**Atleast once in a well**	**A section of a well**	**Each section of a well**	**During entire drilling**
			1	**2**	**3**	**4**	**5**
Impact/ Consequence	**Catastrophic**	**5**	A-5	B-5	C-5	D-5	E-5
	Critical	**4**	A-4	B-4	C-4	D-4	E-4
	Moderate	**3**	A-3	B-3	C-3	D-3	E-3
	Marginal	**2**	A-2	B-2	C-2	D-2	E-2
	Negligible	**1**	A-1	B-1	C-1	D-1	E-1

Low (A-1, B-1, C-1, A-2, B-2)	Risks tolerable: counteractive actions are flexible if they can be applied in a lower amount. For example time period, cost and effort.
Medium (D-1, E-1, C-2, D-2, B-3, C-3, A-4, B-4, A-5)	Take corrective measurements at a suitable time
High (E-2, E-3, D-3, E-4, D-4, C-4, E-5, D-5, C-5)	Risks intolerable: tasks are not allowable until mitigation actions are in place.

Results:

This paper focuses on risk identification, which can influence the drilling project and quantify them by utilizing qualitative risk assessment techniques. Detailed results concluded from this paper are presented in this chapter: Risk management involves the practice of a Risk Register or Risk Log. Risks should be logged on the register when they are discovered, and steps should be taken to mitigate the risk. The following are the random hazards chosen to be shown in the Drilling Project Risk Register out of 111 risks discovered during a rigorous risk identification procedure for our project:

Table 6: Risk Register

Risk ID	Risk Category	Risk Description	Probability	Impact	Risk Rating	Risk Response	Contingency Plan
1.3	Contracts and Procurement	Unclear contract specification	3	1	3	Transfer	Contract specialist services to be hired in order to place a contract as per the industry standards
1.9	Contracts and Procurement	Non-availability of required goods/services in the local market	5	4	20	Avoid	To procure material upfront in order to realize the delay
2.2	Finance & Economics	Decline in Export	1	1	1	Accept	
2.15	Finance & Economics	Global Oil Prices	5	5	25	Mitigate	To run project economic sensitivities on various cases in order to validate the project in the worst-case scenario.
2.17	Finance & Economics	Delayed JV Partners response	4	3	12	Mitigate	Continuous Follow up to answer pending queries.
3.1	Force Majeure	War and country insecurities	1	5	5	Accept	
3.3	Force Majeure	Extreme weather conditions / Rain	4	3	12	Mitigate	Responsive strategy to be implemented for continuous operations
4.6	HSE & Community & Security	Improper disposal of drilling cuttings	1	2	2	Avoid	Special services to procure for effective dumping
4.27	HSE & Community & Security	Toxic gases	3	5	15	Mitigate	Safety precautions to be implemented
4.29	HSE & Community & Security	Well Blowout	5	5	25	Mitigate	Frequent testing of the BOP is to be ensured. Well to be killed if a high kick is identified.
5.6	Information and communications technology	Data Loss	1	4	4	Mitigate	Backups to be ensured
6.1	Legal & Commercial	Investigation by Government Agencies	2	2	4	Accept	Audit to be performed
6.16	Legal & Commercial	Political Influence	4	2	8	Escalate	To be discussed with concerned authorities
7.1	Operational	High Pressure High temperature formation Drilling	1	2	2	Mitigate	Proper controlling systems to be implemented
7.6	Operational	Hard or Soft formation Drilling	2	2	4	Mitigate	Effective Drilling Bits to be used
7.1	Operational	Long lead times for material delivery	3	2	6	Avoid	To procure material upfront in order to realize the delay
7.16	Operational	Loss of Circulation	5	3	15	Mitigate	Efficient hole cleaning to be ensured
7.18	Operational	BOP Failure	4	5	20	Mitigate	Frequent testing of the BOP is to be ensured. Well to be killed if a high kick is identified.
8.1	Policy and political risk	Loss experienced due to bribery and corruption	1	2	2	Escalate	To be discussed with concerned authorities

8.3	Policy and political risk	Low/inadequate budgetary allocation	2	2	4	Avoid	Upfront Planning

The risk matrix for the identified risks has been established based on the risk impact and chances of occurrence standings:

Table 7: Risk Placement

Likelihood ↑					
5	• 4.16	• 4.24 • 4.25	• 7.16 • 7.17	• 1.9 • 2.19	• 2.15 • 4.29
4	• 2.8 • 4.14	• 6.16 • 7.13	• 2.17 • 3.3	• 2.2 • 4.28	• 7.18
3	• 1.3 • 2.6 • 2.7 • 4.7 • 4.9 • 5.1 • 5.2 • 7.5	• 2.21 • 2.22 • 2.23 • 4.17 • 4.18 • 7.8 • 7.1 • 7.11 • 7.12	• 1.7 • 4.23 • 6.17 • 7.14 • 7.15	• 2.16 • 4.26	• 1.8 • 4.27
2	• 1.1 • 2.3 • 4.4 • 4.5 • 7.2	• 1.4 • 1.5 • 1.6 • 2.9 • 2.1 • 2.11 • 4.11 • 4.12 • 4.13 • 5.5 • 6.1 • 7.6 • 7.7 • 8.2 • 8.3	• 2.24 • 4.19 • 4.2 • 5.7 • 5.8 • 6.12 • 6.13 • 6.14 • 6.15 • 7.9	• 2.18 • 4.21 • 4.22	•
1	• 2.1 • 2.2 • 4.1 • 4.2 • 4.3 • 6.1 • 6.2 • 6.3 • 6.4	• 4.6 • 6.5 • 6.6 • 7.1 • 8.1	• 1.2 • 2.4 • 2.5 • 4.8 • 4.1 • 5.3 • 6.7 • 6.8 • 6.9 • 7.3 • 7.4	• 4.15 • 5.4 • 5.6	• 2.12 • 2.13 • 2.14 • 3.1 • 3.2 • 6.11
	1	2	3	4	5
	Impact →				

Numbers in the risk matrix represent Risk ID, which has been designated to each particular risk per the area of interest.

For example, Risk ID: 4.29 refers to the risk "Well blowout".

Risk Breakdown Structure: The risk breakdown structure has been formulated as per the identified risks according to the generalized risk categories (Table). It represents the risk pertaining to each domain or area, which may help in developing monitoring and controlling strategies:

Table 8: Risk breakdown structure

Risk Category	Risk Description
Contracts and Procurement	Change of organization ownership or management
	Changes in the scope of the contract
	Inadequate knowledge of implications for contracts' T&Cs deviations
	Inadequate management of drilling contracts
	Inadequate well planning and budgeting
	Non-availability of required goods/services in the local market
	Poor contract management
	Unclear contract specification
	Weak negotiation position with the supplier (sole source)
Finance & Economics	Appreciation in the exchange rate of currencies other than USD
	Bankruptcy of project partner
	Change in operational priorities resulting in adjustments in work plans
	Changes in bank formalities and regulations
	Decline in Export
	Delay in cash call receipts from JV partners
	Delay in funding from HQ
	Delay of payment to Vendors
	Delayed disbursement of funds from financiers
	Delayed JV Partners response
	Delaying in raising AFEs
	Exchange Rates
	Fiscal Deficit
	Fluctuation of Production targets
	Global Oil Prices
	High cost of drilling
	Inflation Factor
	Interest and Wacc Fluctuation
	Lack of proper monitoring of actual cost vs. approved AFEs
	Low credibility of shareholders and lenders
	Price instability of fuel and steel
	Supply & demand of Gas
	Unforeseen payments/Claims (Tax/Additional Works)
	Variation of Prices for Material

Force Majeure	Earthquakes
	Extreme weather conditions / Rain
	War and country insecurities
HSE & Community & Security	Air pollution due to using a diesel generator
	Awareness of community
	Business Growth and development resulting in extra exposure
	CO2 Emission Issues
	Community Barrier
	Community issues
	Community strikes
	Corporate Social Responsibility impacts
	Cultural barriers
	Damage to Remote Cultivated Ares
	Equipment and personnel safety
	Improper disposal of drilling cuttings
	Lack of communication for Emergency Planning
	Lack of Emergency Preparedness
	Leakage or collapse of the brine pond
	Local Hiring
	Management of community relationships
	Noise
	Overall law and order situation
	Project Impacts/ outcome acceptance by stakeholders
	Religious barriers
	Risk of Ignition
	Safety awareness (Opportunity)
	Staff Security in remote areas
	Surface Contamination / Fluid Leakage
	Thermal and chemical pollution
	Toxic gases (CO2, H2S released from the well)
	Waste Pollution in well development area
	Well Blowout
Information and communications technology	Data Loss
	External factors i.e. communication breakdown, environmental factor(a/c, water, etc)
	Hardware failure
	Malfunction of hardware
	Natural Calamity
	Power Failure
	System Failure (applications, software)
	Viral attack on systems/ applications
Legal & Commercial	Financial Institution restrictions
	International constraints
	Lobbying by different groups
	Political changes
	Shifting priorities of the government
	Breach of contract by project partner
	Cartel/Market Abuse
	Corruption
	Frequent changes in policies
	Improper verification of contract documents
	Investigation by Government Agencies
	Kickbacks/Bribes
	New discoveries of Market Competitors
	New entrants/technologies
	Political Influence
	Political Instability
	Social Unrest
Operational	BOP Failure
	Casing Wear during Well Case
	Cement Hardening inside Casing
	Drill Pipe Failure
	Engines failure
	Hard or Soft formation Drilling
	High Pressure High temperature formation Drilling
	Long lead times for material delivery
	Loss of Circulation
	Loss of tools in Well
	Mud Pumps failure
	Non-productive well:
	Parted Casing (Threads problem)
	Plugged and abandoned well
	Poor materials quality
	Stuck Pipe
	Suspended well - not completed:
	Wellbore Instability
Policy and political risk	Cost increase due to changes in Government policies
	Loss incurred due to corruption and bribery
	Low/inadequate budgetary allocation

Conclusion

Development drilling is highly influenced by multiple complicated processes and highly advanced technology. Since it contains high risk, competing technology, and higher investments with higher returns, therefore its level is considerably up to the space technology and its projects. Drilling expenditures make up approximately 40% of the total cost of a well development, marking it as a significant area where noticeable concentration and advance planning, monitoring, and control are required. Furthermore, the drilling process is beset by several risks that drive up costs and adversely affect well delivery.

Considering the importance of risk management for said projects, the study focused on the literature review that highlights the processes, procedures, and models for drilling risk management. Recognized risk through a rigorous and comprehensive risk identification process has been evaluated with the qualitative risk assessment approach. The risk register for development drilling projects has been developed along with the risk matrix as per the defined criteria of risk impact and probability for drilling. Furthermore, a detailed risk breakdown structure has been formulated according to the general area categorization to enlighten the risks focused on each area of interest. Overall, the study will provide a value-added and detailed risk management approach for new ventures, which may be planned with the implementation of comprehensive drilling risk management.

Paper findings were based on generalized risk identification techniques. However, existing frameworks in industries such as PASTEL (Political, Economical, Social, Technological, Legal and Environmental) and TECOP (Technical, Economic, Commercial, Operational, or Political) may be utilized for better risk documentation. Furthermore, the study focused on qualitative risk assessment for identified risks. However, a detailed quantitative risk assessment approach will bring more information by computing the cost related to each risk and the cost of mitigation actions. Integrated cost & schedule risk analysis based on the available well data (recently completed projects) is also recommended for future works.

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