

# Analysis of the Delay Risk of the Engineering, Procurement, Construction, and Commissioning (EPCC) Phases in Oil and Gas Industry Projects

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## ABSTRACT

EPCC projects in the oil and gas industry are highly complex and carry significant risks of delays and cost overruns. This study aims to identify and analyze the dominant delay risk factors across each phase of EPCC, using the Matindok Gas Development Project in Central Sulawesi, Indonesia, as a case study. The project was originally scheduled for completion within 26 months, but experienced a time extension of up to 12 months. Data collection was conducted through a literature review and the distribution of questionnaires. Risk evaluation was performed based on the probability and impact of each factor using the Risk Priority Number (RPN) method. The results show that the most critical risk factors include design changes by the project owner during the engineering phase (RPN = 13.21), poor cash flow of the parent company in the procurement phase (RPN = 13.2), work sequence conflicts in the field during the construction phase (RPN = 11.23), and incomplete cross-discipline work during the commissioning phase (RPN = 9.93). These findings highlight the importance of implementing integrated risk management strategies across all EPCC phases to prevent delays and ensure timely project completion.

*Keywords-risk; EPCC project; RPN; engineering; procurement; construction; commissioning*

## I. INTRODUCTION

The EPCC general contracting model is a popular method for large-scale engineering and construction projects [1]. EPCC projects depend heavily on seamless transitions between work phases [2]. Both EPCC and construction projects are typically highly complex and uncertain. The complexity of EPCC projects links one process to another, which can cause multiplier effects if any process changes in planning, scheduling, technical aspects, or quality, impacting other functions like procurement, construction, and commissioning [3]. The EPCC system requires contractors to manage engineering, procurement, and construction of a single project that involves diverse expertise. Upon obtaining an EPCC lump sum contract, contractors assume the risk of cost variations caused by their own design decisions. They also base their bids on the Front-End Engineering Design (FEED). This aligns well with the EPCC concept, where the contractor is responsible for

the design [4]. Design professionals face specific design risks, but project stakeholders, such as owners or contractors, also face general design risks depending on their roles and responsibilities. The main design risks include design changes or deficiencies, poor designs, and difficulties in adhering to standards. During construction, the contractor may encounter many challenges if project quality is not maintained. Therefore, minimizing risks requires careful management of the design documents' consistency with geological data, high-quality supervision, control, and assurance processes, and the construction methods proposed by the contractor [5]. If risk management in the contract is inadequate, the entire project might fail to meet its objectives. Managing project risks involves planning, identifying potential risks, assessing their impacts, developing mitigation plans, and monitoring risks continuously [6]. Building complex engineering projects demands a high level of expertise, advanced machinery, and well-coordinated teams with sufficient financial resources,

which often exceeds the capacity of a single contractor [7]. Under an EPCC contract, the contractor is fully responsible for executing all project activities. As EPCC contracts are typically structured as lump-sum turnkey agreements and awarded to the lowest bidder, contractors are exposed to significant financial, technical, and managerial risks. Failure to adequately identify and manage these risks may result in schedule delays and adverse impacts on overall project performance [8].

Many EPCC projects have experienced schedule delays, including the Matindok Gas Development Project in Central Sulawesi, Indonesia. This project was originally planned for completion within 26 months, but ultimately required an additional 12 months to complete. These delays motivated the present study to examine the causes of scheduled overruns in oil and gas EPCC projects. While previous studies have largely concentrated on individual EPCC phases, such as engineering, procurement, or construction, limited attention has been given to the project lifecycle. In particular, the commissioning phase, which represents the final and critical stage of EPCC projects, has often been overlooked. This omission is significant because delays during commissioning can directly affect overall project completion. To address this research gap, the present study incorporates the commissioning phase into the analysis and evaluates its contribution to delays across the entire EPCC project lifecycle.

## II. MATERIALS AND METHODS

### A. EPCC Project

A project is a temporary endeavor undertaken to create a unique product, service, or outcome. The project life cycle consists of a series of phases that facilitate the delivery of value to businesses and stakeholders from project initiation to completion. These phases provide a structured framework for managing the pace, sequence, and methods used to achieve project objectives [9]. The term "EPCC" refers to a specific contractual arrangement commonly applied in complex engineering projects. Under this contract model, the EPCC contractor assumes responsibility for the full scope of work, including engineering, procurement, construction, commissioning, and final handovers to the owner or operator. EPCC projects are typically large-scale and highly complex, and are widely implemented in sectors such as oil and gas, industrial facilities, mining, power generation, and major infrastructure development [10]. In an EPCC contract, the contractor is fully accountable for the adequacy, stability, and safety of all construction methods, operational activities, and executed works [11]. Due to the comprehensive nature of this general contracting model, EPCC contractors face substantial risks, including high manufacturing and management costs, extensive coordination requirements, and significant organizational complexity. Furthermore, EPCC projects involve multiple stakeholders and interfaces, requiring careful management of relationships and conflicting interests, which collectively contribute to increased project risk exposure [12].

### B. Engineering Phase Risk

The design phase is a critical component of EPCC projects, as it is characterized by a high level of uncertainty at the early stages. This phase presents key opportunities for value creation,

where effective engineering management can significantly enhance overall project performance [12]. However, the engineering phase is also associated with various risks, including discrepancies between design assumptions and actual field conditions, delays in obtaining design approvals from planning consultants, and incomplete or insufficiently detailed engineering designs. If not properly managed, these risks can propagate to subsequent project phases and contribute to schedule delays [13].

### C. Procurement Phase Risk

Procurement activities in EPCC projects are conducted concurrently with both the engineering and construction phases. Due to this overlap, procurement-related issues can have cascading effects on project cost and schedule performance [14]. Risks during the procurement phase may arise from inadequate management of cost, quality, processes, and security. Additional sources of risk include the absence of a comprehensive procurement plan, delays in obtaining supplier approvals, errors in equipment calibration, inaccurate cost estimations, incorrect process assumptions, and ineffective forecasting or progress tracking. Collectively, these deficiencies can cause significant deviations between planned and actual project outcomes, ultimately contributing to project delays and cost overruns [15].

### D. Construction Phase Risk

Construction projects frequently encounter a range of challenges during the execution phase, which can significantly affect project performance. Previous studies have identified several critical issues, including resource management, schedule control, cost management, quality assurance, safety management, complexity handling, change management, uncertainty mitigation, and ineffective communication. The success or failure of a construction project largely depends on how effectively these challenges are addressed and managed throughout the construction process [16].

### E. Commissioning Phase Risk

Effective early startup methodologies emphasize thorough planning and systematic execution to mitigate risks during the commissioning of complex gas processing systems. Techniques such as phased startup, where system components are activated sequentially, allow teams to test, integrate, and validate individual subsystems in a controlled manner. This approach facilitates early identification and resolution of potential issues, thereby reducing the likelihood of costly delays during full-scale system operation [17].

### F. Risk Management

Risk is defined as the effect of uncertainty on objectives and may result in positive, negative, or combined outcomes, including opportunities, threats, or unforeseen conditions. Objectives may vary in scope and level, and risks can manifest across different stages and organizational hierarchies. Risk is commonly characterized by its source, potential events, consequences, and the likelihood of occurrence [18]. In construction projects, the adverse impacts of risk can extend beyond project managers and contractors to include financial losses, reputational damage, and negative effects on

professionals and stakeholders involved. Identifying existing risks and implementing timely mitigation measures is particularly challenging in large-scale projects due to their complexity, scale, and dynamic environments. Consequently, effective risk identification and management are critical to minimizing losses and ensuring project success [19].

G. Research Operational Framework

An operational framework was developed to achieve the research objectives of this study. The elements and indicators associated with each phase of the EPCC project were identified through a comprehensive review of relevant prior research. Data collection for Research Question 1 (RQ1) involved compiling potential delay risk factors from established journal

sources, which were subsequently validated through an opinion survey administered to industry practitioners. Research Question 2 (RQ2) focused on quantifying the causal relationships between these elements and indicators and their impact on project delays. To address this objective, a questionnaire survey was conducted among respondents from EPCC contractor organizations, including personnel from management, engineering, procurement, construction, and commissioning teams. The collected data were analyzed using descriptive statistical methods, including mean values, frequencies, and percentages. The results identify the dominant risk factors contributing to delays in EPCC projects, as illustrated in Figure 1.

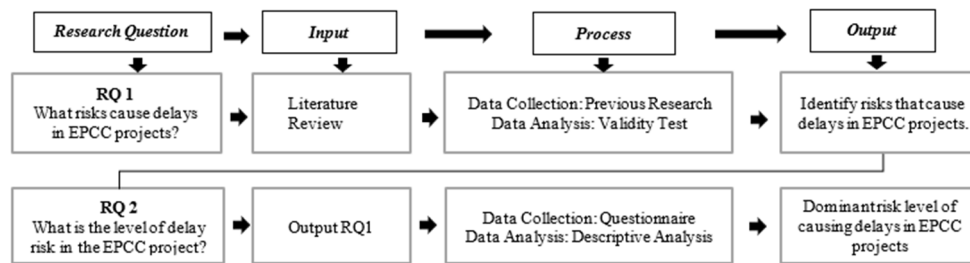


Fig. 1. Operational framework.

Descriptive analysis was employed to summarize and interpret the characteristics of the data collected through a questionnaire survey. The questionnaire was designed to capture respondents' perceptions of the probability and impact of each identified delay risk indicator. A five-point Likert scale was used, where a score of 1 represents the lowest probability or impact and a score of 5 represents the highest. Risk assessment was conducted through two main components: the likelihood of a risk occurring and the magnitude of its potential impact on the project schedule. Both components were evaluated using the same five-point Likert scale to ensure consistency in measurement. The detailed criteria for probability and impact assessment are presented in Tables I and II [20].

TABLE I. PROBABILITY

Category	Criteria	Index
Almost certain	Cause the serious problem is > 80%-100%	5
Likely	Likely to occur > 60%-80%	4
Moderate	Occasional > 40%-60%	3
Unlikely	Unlikely to occur > 20%-40%	2
Rare	Less likely to occur ≤ 20%	1

TABLE II. IMPACT

Level	Criteria	Index
Severe	Delay schedule > 5% of project time	5
Major	Delay schedule 2%-5% of project time	4
Significant	Delay schedule 1%-2% of project time	3
Minor	Delay schedule 0.5%-1% of project time	2
Insignificant	Delay schedule ≤ 0.5% of project time	1

TABLE III. INDICATOR ENGINEERING

Element	Indicators Engineering	References
X1.1	Incomplete and inaccurate required data, such as soil investigation results, Detailed Engineering Design (DED), etc.	[3, 15]
X1.2	Changes requested by the owner, such as material specification modifications or the addition of new items to support plant operations.	[3, 15]
X1.3	Low team productivity in preparing documents, such as Request for Quotation (RFQ), Issued For Approval (IFA), and/or Issued For Construction (IFC) drawings, Material Take-Off (MTO), and Material Approval.	[3, 15]
X1.4	Inconsistency between detailed design and field conditions (constructability), e.g., steel structures, piping, and mechanical components.	[3, 15]
X1.5	Inaccurate and unsystematic control of drawings and documents.	[3, 15]
X1.6	Lack of coordination and communication with related parties, such as the owner, Project Management Consultant (PMC), or internal contractor teams.	[3]
X1.7	Lack of competence and experience within the team to perform design work, review designs, and resolve field issues.	[3]
X1.8	Design changes from other disciplines, such as mechanical, piping, tank, electrical, etc.	[3]
X1.9	Excessive workload (overload), requiring extensive resources.	[15]
X1.10	An incomplete in-house engineering team results in outsourcing design work to third parties.	[15]
X1.11	Delay in receiving feeding data from other members of the Joint Operation (JO) consortium.	[19]
X1.12	Delays in approval from the client and/or PMC.	[15]
X1.13	Interface issues with existing buildings when the project site is located in an existing plant area.	[15]

TABLE IV. INDICATOR PROCUREMENT

Element	Indicators	References
<b>X2</b>	<b>Procurement</b>	
X2.1	Delay in receiving RFQ and material approval documents from the engineering team.	[2, 21]
X2.2	Lack of communication between external stakeholders (subcontractors, vendors, and suppliers) and the field team.	[2, 15]
X2.3	Changes in the Scope of Work (SOW) of the work package from engineering.	[2, 15, 21]
X2.4	Material specifications that are not common in the country require them to be imported from abroad.	[2, 15]
X2.5	Subcontractor/vendor/supplier offers are not comparable, making it impossible to meet technical, commercial, Quality Control (QC), and safety requirements.	[2]
X2.6	The review and approval process for contract signatures by both parties (between the main contractor and subcontractor) takes a long time.	[2, 15]
X2.7	The selection process for subcontractors, vendors, and suppliers is inadequate and does not follow procedures (conflict of interest).	[2]
X2.8	The manufacturing process for materials in the workshop takes a long time.	[19]
X2.9	Packing and handling of materials is difficult due to their large dimensions.	[3]
X2.10	The parent company's cash flow is poor, resulting in delayed payments to subcontractors/vendors/suppliers.	[2, 15]
X2.11	The customs clearance process at the port takes a long time, causing materials to arrive late at the site.	[15, 21]
X2.12	Delays in the delivery of materials such as sand, gravel, rebar, and long lead items from overseas.	[19]
X2.13	The project's location and geographical conditions are in a remote area, making it difficult to deliver materials to the site.	[15]

TABLE V. INDICATOR CONSTRUCTION

Element	Indicators	References
<b>X3</b>	<b>Construction</b>	
X3.1	Failure to create a workfront Project Execution Plan (PEP), such as labor requirements, materials, equipment, and site readiness.	[3, 15]
X3.2	Lack of communication between relevant parties, both internally and externally.	[2, 15]
X3.3	Lack of competence among recruited workers' results in low productivity in the field.	[15, 21]
X3.4	Carelessness when reviewing documents, such as IFC drawings.	[15]
X3.5	The impact of the sequence of work on-site, leading to crowded interfaces with other work, such as underground piping work.	[3, 15, 21]
X3.6	Damage and poor material quality due to handling processes and prolonged storage in the warehouse.	[3]
X3.7	Delays in the delivery of construction equipment, such as cranes, pile drivers, excavators, etc.	[3, 21]
X3.8	Errors in the implementation of work methods.	[3, 15]
X3.9	Insufficient supervision of work on-site.	[22]
X3.10	Construction drawings that are unrealistic and cannot be applied on-site.	[3, 21]
X3.11	Insufficient QC oversight leading to rework (repairs).	[15]
X3.12	Construction equipment unable to function properly (damaged), such as cranes, excavators, etc.	[15]
X3.13	HSE issues, such as workplace accidents, and compliance with owner safety standards, like Medical Check Up (MCU), training, and traffic management.	[15]
X3.14	Worker protests due to issues with local labor recruitment or other issues, such as wages.	[15]

TABLE VI. INDICATOR COMMISSIONING PHASE

Element	Indicators	References
<b>X4</b>	<b>Commissioning</b>	
X4.1	Delays in closing punch lists and safety diagnoses, or Pre-Startup Safety Review (PSSR).	[22]
X4.2	Limitations on the commissioning team's work area due to other activities that could interfere, such as X-rays on pipes.	[23]
X4.3	Delays in the handover of documents from QC to the precommissioning team.	[23]
X4.4	Outstanding remaining work from other disciplines, such as civil, mechanical, electrical, and piping work.	[24]
X4.5	Limitations in manpower and equipment for precommissioning activities, such as hydrotests/leak tests, flushing/blowing, solo runs, N <sub>2</sub> purging, terminations, and loop tests.	[24]
X4.6	Additional work is required due to non-compliance with safety/security standards during operations, e.g., additional handrails, stairs, and platforms.	[24]
X4.7	Delays in the delivery of materials and equipment for the precommissioning process, such as compressors, blowers, nitrogens, generators, fuel, etc.	[25]
X4.8	Availability of power supply for running mechanical static and rotating equipment during precommissioning activities.	[25]
X4.9	Availability of supporting facilities (utilities) for precommissioning activities, such as eyewash stations, firefighting equipment, and retention ponds.	[25]
X4.10	Damage or leaks in installed equipment during performance testing.	[26]
X4.11	Operators hired by the owner are not yet proficient in system operation, such as in the control room.	[27]

#### H. Data Acquisition

Based on previous research, 51 indicator factors that influence EPCC project delays were identified. There are 13 indicators for the engineering stage (X1), 13 for the procurement stage (X2), 14 for the construction stage (X3), and 11 for the commissioning stage (X4). These factors are presented in Table III.

#### I. Methodology

The methodology used in this paper is:

- This study focuses on analyzing the delay risk of the EPCC phases in oil and gas industry projects.
- Sample size and target population involved a minimum of 120 respondents, consisting of employees working for

EPCC contractors. The target population was all operational workers exposed to the delay risk.

- Participants' selection criteria were chosen using purposive sampling, with the inclusion criteria of having a minimum of a high school diploma, and a minimum work experience of 0-5 years, and were directly involved in operational tasks.
- Data were collected through a self-administered questionnaire distributed via Google Forms.
- The questionnaire consisted of three main sections: demographic information, perception and awareness of delay risk in the EPCC project, and work experience. This questionnaire allows efficient data collection from a relatively large group and captures workers' perceptions and experiences quantitatively.
- The collected data were analyzed using descriptive statistics (mean, frequency, and percentage).
- The 5-point Likert scale was used to provide a balanced range of responses from "rare" to "almost certain" for probability, and from "insignificant" to "severe" for impact, which is easy for respondents to understand, reduces ambiguity, and provides sufficient variability for statistical analysis.

#### J. Data Analysis

##### 1) Validity Test

The purpose of the validity test is to assess whether the questionnaire accurately measures the intended research variables. A questionnaire is considered valid when it effectively captures the constructs being investigated, ensuring that respondents' answers accurately represent the expected data. Validity was evaluated by comparing the calculated correlation coefficient (r-calculated) with the critical value from the correlation table (r-table). If the r-calculated value exceeds the r-table value, the indicator is deemed valid; otherwise, it is considered invalid.

##### 2) Reliability Test

An instrument is deemed reliable when it consistently generates measurements that reflect actual conditions. The reliability of the questionnaire was assessed using Cronbach's alpha, with values above 0.6 indicating acceptable internal consistency.

##### 3) RPN

The effect of risk can be evaluated by multiplying the probability of occurrence (P) by the impact of the risk (I), resulting in a Risk Score, also referred to as the RPN. The RPN method quantifies risk by integrating these two key factors, P and I, into a single numerical value that represents the relative significance of each risk. The RPN for each identified risk is calculated using:

$$RPN = P \times I \quad (1)$$

The RPN value is first calculated for each individual risk indicator. Subsequently, the RPN values for each project phase

or work activity are determined by averaging the RPN values of all associated risk indicators. This approach enables the identification of project phases or activities with relatively high risk levels. To determine which RPN values are considered critical, several methods may be applied, such as establishing a predefined RPN threshold or selecting the highest-ranking RPN values for further analysis and mitigation.

### III. RESULTS AND DISCUSSION

#### A. Analyzing Information from Survey Respondents

This study is based on a questionnaire survey in which the identified delay risk factors were presented to respondents from EPCC contractor organizations, including personnel from the management, engineering, procurement, construction, and commissioning teams, as illustrated in Figure 2. To ensure the reliability of the collected data, only respondents who met the predefined inclusion criteria were considered, namely having a minimum educational qualification of a high school diploma and a minimum work experience of 0–5 years, as shown in Figures 3 and 4. A total of 123 questionnaires were distributed via Google Forms; however, 16 responses were deemed incomplete or unsuitable and were therefore excluded. Consequently, 107 valid questionnaires were retained for further analysis. The demographic characteristics of the respondents are presented in Figures 2-4.

#### B. Respondent Characteristics' Summary

Figure 2 shows the distribution of respondents based on their project team composition. The respondents were distributed across five main project teams. The largest proportion was from the management team (25.23%), followed by the construction team (21.5%), the procurement team (20.56%), the engineering team (17.76%), and the commissioning team (14.95%). This distribution indicates that most respondents were engaged in managerial and construction-related activities, which are central to the execution of EPCC projects. Figure 3 displays the distribution of respondents according to their educational background. Most participants held a bachelor's degree (64.49%), followed by those with a master's degree (20.56%), while respondents with a diploma and high school education accounted for 7.48% each. None of the respondents possessed a doctoral degree. This distribution suggests that most respondents have higher educational qualifications, supporting their competence and understanding of engineering and project management practices. As shown in Figure 4, the respondents' years of work experience varied across several categories. The highest proportion had 10-15 years of experience (36.45%), followed by 15-20 years (28.97%), 5-10 years (23.36%), more than 20 years (6.54%), and less than 5 years (4.67%). These results suggest that most of the respondents were experienced professionals, ensuring that the collected data accurately reflected practical conditions in EPCC project environments.



Fig. 2. Respondent's division.

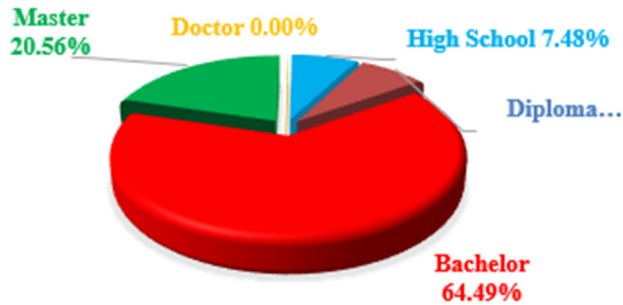


Fig. 3. Respondent's education.

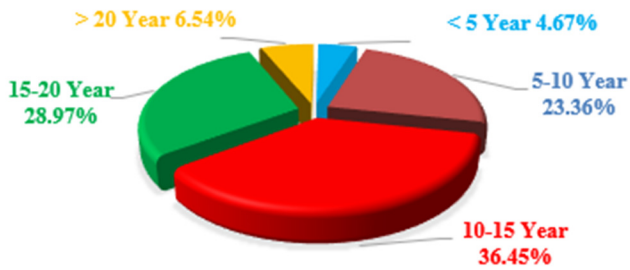


Fig. 4. Respondent's work experience.

C. Validity Test

The validity test aimed to ensure that the questionnaire accurately measured the intended variables. Validity testing was conducted using Microsoft Excel 2023. The parameters used to assess validity testing were a comparison of the table r with the calculated r and a significance level of 1% with a total of 107 respondents.

Table VII presents the results of the validity test for each indicator in the research instrument, covering four main variables: Engineering (X1), Procurement (X2), Construction (X3), and Commissioning (X4). Each indicator was tested using the correlation coefficient (r-calculated) and compared with the r-table value (0.25) at a 1% significance level. All r-calculated values are higher than the r-table, indicating that all indicators are valid and appropriately measure the intended constructs within each EPCC project phase.

TABLE VII. RESULTS OF VALIDITY TEST

Code	R calculate	R table	Conclusion
<b>X1</b>	<b>Engineering</b>		
X1.1	0.38	0.25	Valid
X1.2	0.47	0.25	Valid
X1.3	0.38	0.25	Valid
X1.4	0.51	0.25	Valid
X1.5	0.47	0.25	Valid
X1.6	0.61	0.25	Valid
X1.7	0.57	0.25	Valid
X1.8	0.56	0.25	Valid
X1.9	0.45	0.25	Valid
X1.10	0.61	0.25	Valid
X1.11	0.60	0.25	Valid
X1.12	0.55	0.25	Valid
X1.13	0.60	0.25	Valid
<b>X2</b>	<b>Procurement</b>		
X2.1	0.75	0.25	Valid
X2.2	0.67	0.25	Valid
X2.3	0.57	0.25	Valid
X2.4	0.59	0.25	Valid
X2.5	0.70	0.25	Valid
X2.6	0.63	0.25	Valid
X2.7	0.61	0.25	Valid
X2.8	0.69	0.25	Valid
X2.9	0.58	0.25	Valid
X2.10	0.61	0.25	Valid
X2.11	0.73	0.25	Valid
X2.12	0.75	0.25	Valid
X2.13	0.64	0.25	Valid
<b>X3</b>	<b>Construction</b>		
X3.1	0.72	0.25	Valid
X3.2	0.72	0.25	Valid
X3.3	0.73	0.25	Valid
X3.4	0.79	0.25	Valid
X3.5	0.69	0.25	Valid
X3.6	0.72	0.25	Valid
X3.7	0.75	0.25	Valid
X3.8	0.70	0.25	Valid
X3.9	0.71	0.25	Valid
X3.10	0.71	0.25	Valid
X3.11	0.70	0.25	Valid
X3.12	0.69	0.25	Valid
X3.13	0.65	0.25	Valid
X3.14	0.35	0.25	Valid
<b>X4</b>	<b>Commissioning</b>		
X4.1	0.65	0.25	Valid
X4.2	0.66	0.25	Valid
X4.3	0.64	0.25	Valid
X4.4	0.72	0.25	Valid
X4.5	0.64	0.25	Valid
X4.6	0.64	0.25	Valid
X4.7	0.66	0.25	Valid
X4.8	0.66	0.25	Valid
X4.9	0.59	0.25	Valid
X4.10	0.65	0.25	Valid
X4.11	0.67	0.25	Valid

D. Reliability Test

To guarantee consistency in subsequent measures, the reliability test checked the questionnaire's internal consistency. If an item's Cronbach's alpha value was higher than 0.60, it was deemed dependable. The results of the reliability test are presented in Table VIII.

TABLE VIII. RESULTS OF RELIABILITY TEST

Variants	Variant total	Result	Conclusion
1493.3	30085.7	0.96	Reliable

Table VIII illustrates the results of the reliability test for the overall research instrument. The total variance score of 1,493.30 and the total item variance of 30,085.7 produced a reliability coefficient (r) of 0.96, which exceeds the minimum acceptable threshold of 0.6. This indicates that the questionnaire is highly reliable and consistently measures the research variables across all EPCC project phases. Based on the questionnaire responses, each respondent evaluated the probability and impact of each identified risk factor during the EPCC stages. The RPN for each indicator was calculated by multiplying the corresponding probability and impact values. These RPN values were then averaged for analysis, as presented in Table IX and Figure 5.

The risk analysis results presented in Figure 5 reveal that the highest RPN values are distributed across all phases of the EPCC project. In the engineering phase, indicator X1.2, changes requested by the owner, such as material specification modifications or the addition of new items to support plant operations, obtained the highest RPN value, 13.21. This implies that design changes or specification modifications at the early stage have the most significant impact on project performance. In the procurement phase, indicator X2.10 demonstrated a high RPN value of 13.2, indicating that poor cash flow management could disrupt payment flows to subcontractors, vendors, and suppliers. This condition may weaken supply chain performance and delay subsequent construction activities. Therefore, effective cash flow planning and well-structured payment strategies are crucial to maintaining procurement stability and supporting overall project performance. In the construction phase, indicator X3.5 (RPN 11.23) demonstrates that work sequencing plays a critical role in ensuring schedule accuracy. Considering the multidisciplinary nature of EPCC projects, strong collaboration, coordination, and communication among stakeholders are essential to maintain construction performance and avoid delays, thereby facilitating the timely commencement of commissioning activities. In the

commissioning phase, indicator X4.4 (RPN 9.93) reveals that residual works from other disciplines (minor activities) may delay the initiation of testing and commissioning processes. This is due to the requirement that testing activities be conducted in areas free from parallel work to safeguard equipment performance and ensure the safety of plant operations. Consequently, the active involvement of the design, procurement, and construction teams is crucial to sustaining commissioning performance as the final stage of the project life cycle, thereby enabling timely and smooth plant operation.

TABLE IX. AVERAGE RPN

Element	RPN	Element	RPN
<b>X1. Engineering</b>		<b>X2. Procurement</b>	
X1.1	11.21	X2.1	10.64
X1.2	13.21	X2.2	9.93
X1.3	12.18	X2.3	10.33
X1.4	11.76	X2.4	9.87
X1.5	8.38	X2.5	9.87
X1.6	9.49	X2.6	9.24
X1.7	9.95	X2.7	9.09
X1.8	12.34	X2.8	11.34
X1.9	11.34	X2.9	7.98
X1.10	9.54	X2.10	13.2
X1.11	9.85	X2.11	9.64
X1.12	13.2	X2.12	10.93
X1.13	10.81	X2.13	11.55
<b>X3. Construction</b>		<b>X4. Commissioning</b>	
X3.1	9.79	X4.1	9.89
X3.2	9.75	X4.2	8.15
X3.3	10.00	X4.3	8.25
X3.4	9.94	X4.4	9.93
X3.5	11.23	X4.5	8.53
X3.6	8.86	X4.6	8.79
X3.7	10.00	X4.7	8.96
X3.8	9.09	X4.8	8.56
X3.9	8.89	X4.9	7.76
X3.10	8.18	X4.10	8.67
X3.11	9.65	X4.11	8.07
X3.12	8.85		
X3.13	8.99		
X3.14	9.46		
X3.15	8.15		
X3.16	8.25		
X3.17	9.93		
X3.18	8.53		
X3.19	8.79		
X3.20	8.96		
X3.21	8.56		
X3.22	7.76		
X3.23	8.67		
X3.24	8.07		

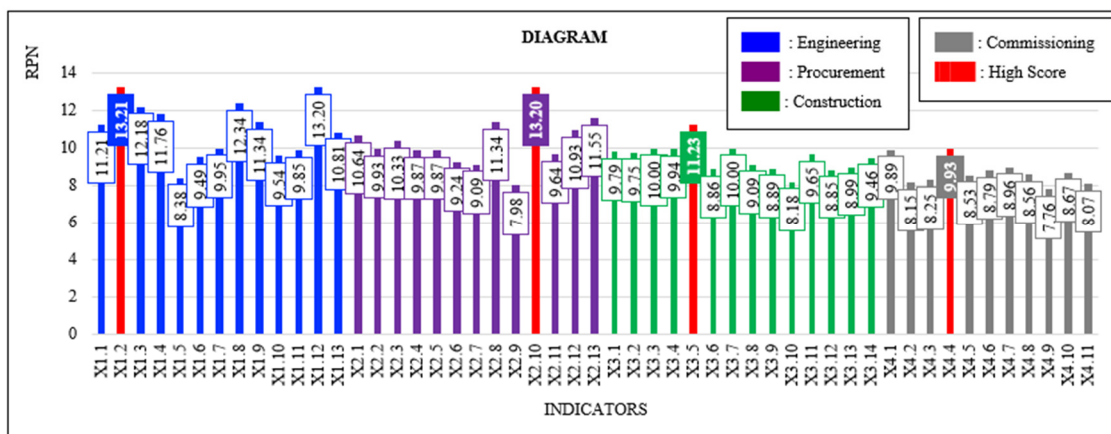


Fig. 5. RPN diagram.

#### IV. CONCLUSIONS

The study identified key delay risk factors contributing to schedule delays in oil and gas industry projects, categorized into four phases: engineering, procurement, construction, and commissioning. The most influential factors engineering phase were regarding changes desired by the owner (X1.2), the procurement phase about the parent company's poor cash flow (X2.10), construction phase about the influence of the sequence of work in the field (X3.5), and commissioning phase were the outstanding remaining work from other disciplines (X4.4), significantly contribute to project delays. The findings of this study have several implications for EPCC oil and gas projects. First, early identification of scope changes by the owner can minimize delays and cost overruns, thereby improving overall project efficiency. Second, the role of top management in making decisions and managing spending patterns on large-scale projects, especially EPCC projects. Third, there is a need for communication and coordination between the parties involved in construction work to avoid changes in the sequence of work that could cause project delays. Finally, the engineer's role is to ensure good planning in the design process so that there is no remaining work that could cause delays in project completion. By addressing this, the reliability of project schedules can be enhanced and ensure smoother transitions between phases. Future studies are proposed to expand the scope of analysis by including more diverse EPCC projects across different regions and project scales. Further research may also incorporate advanced statistical or simulation-based risk assessment methods to validate the findings and explore the dynamic interactions between EPCC delays.

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