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Development of a Risk-Based Standard Operating Procedure to Improve Time and Cost Performance in EPC Projects: A Case Study of a Water Treatment Project at PT XYZ

Muhammad Trijadir*, Wisnu Isvara, Titi Sari Nurul Rachmawati
Universitas Indonesia, Indonesia
Email: muhammad.trijadir@gmail.com*, wisnu.isvara1@ui.ac.id, titisari.nurul@gmail.com

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Abstract

Engineering, Procurement, and Construction (EPC) projects are highly complex due to the strong interdependencies among engineering, procurement, and construction phases, thereby requiring an integrated control system to maintain project schedule and cost performance. However, several EPC projects at PT XYZ have experienced schedule delays and cost overruns caused by weaknesses in process control, cross-functional coordination, technical verification, document management, and decision-making during project execution. In addition, PT XYZ does not yet have a Standard Operating Procedure (SOP) specifically designed to govern EPC project execution. This study aims to develop a risk-based SOP to improve schedule and cost performance in EPC projects, using a Water Treatment project at PT XYZ as a case study. This study employed a mixed-methods approach consisting of six stages: EPC project activity mapping, stakeholder mapping, risk identification, dominant risk determination, risk response development, and risk-based SOP development. Data were collected through a literature review, project archive analysis, field observations, questionnaires administered to 30 respondents, and expert validation. The results identified 104 risks across all EPC project phases, of which 61 were classified as dominant risks requiring priority control measures, comprising 29 risks predominantly affecting schedule performance and 32 risks predominantly affecting cost performance. The study developed a risk-based SOP that integrates project phases, stakeholders, dominant risks, and risk responses through enhanced verification mechanisms, decision gates, supporting documents, and adjustments to stakeholder roles and responsibilities.

INTRODUCTION

Engineering, Procurement, and Construction (EPC) is one of the most widely adopted project delivery methods in the infrastructure, energy, industrial, and utility sectors because it integrates engineering, procurement, and construction processes into a single integrated project execution system (Aldhaheri, Bakchan, and Sandhu 2018; Amiri Ara, Paardenkooper, and van Duin 2022; Huang et al. 2024; Huang and Fu 2024; Tsolas 2020). Compared with conventional project delivery methods, EPC projects are more complex due to the strong interdependence among project phases, the large number of stakeholders involved, and the high degree of dependency among activities throughout the project life cycle. Delays or issues occurring in one phase may trigger cascading effects that impact subsequent phases, making process control a critical factor in achieving project objectives, particularly in maintaining schedule and cost performance (Alemayehu et al. 2024; Ogundipe 2024).

Despite the advantages offered by the EPC approach, its implementation continues to face various challenges that may affect project success (Akhtar 2020; Khairullah, Hilal, and Burhan 2023; Leila 2024; Song and Lu 2025). Previous studies have shown that schedule delays and cost overruns in EPC projects are not solely caused by technical issues encountered during construction activities, but are also influenced by weak stakeholder coordination, delays in decision-making, inconsistencies in technical data, delays in the design process, suboptimal verification mechanisms, and inadequate change control throughout project execution (Wu et al., 2010; Lin, 2016; Sarwani et al., 2024). These conditions indicate that the success of EPC projects largely depends on an organization's ability to establish an integrated control system across all project phases.

PT XYZ is one of the companies involved in the execution of EPC projects, including Water Treatment projects (Kahfi, Bintoro, and Nugroho 2020; Sihombing and Prabowo 2026; Vo, Yang, and Rangasamy 2025; Wicaksono and Isvara 2024). However, based on project evaluation results and company archive analysis, several previous EPC projects experienced deviations from schedule and cost targets due to issues related to cross-functional coordination, inconsistencies in technical data, delays in verification processes, weak document control, and delays in decision-making during project execution. In addition, although PT XYZ has established an EPC business process mapping and an EPC project context diagram, it does not yet have a Standard Operating Procedure (SOP) specifically designed to govern integrated EPC project execution. This condition has resulted in several critical activities lacking adequately documented control mechanisms, thereby increasing the risk of schedule delays and cost overruns (Alshihri, Al-Gahtani, and Almohsen 2022; Daoud, El Hefnawy, and Wefki 2023; Islam, Nepal, and Skitmore 2025; Nguyen et al. 2024).

Risk management is one of the approaches that can be used to strengthen the project control system. ISO 31000:2018 defines risk management as coordinated activities to direct and control an organization with regard to risk through the processes of risk identification, risk analysis, risk evaluation, and risk treatment. In the context of EPC projects, integrating risk management into operational processes is essential because most risks are closely associated with organizational work processes. Therefore, risk management should not only focus on risk identification but should also be integrated into the operational procedures used throughout project execution.

Previous studies have extensively examined risk identification, risk prioritization, and mitigation strategies in EPC projects. However, most studies have primarily focused on developing risk registers and conceptual mitigation recommendations, while studies that integrate EPC project phases, stakeholders, dominant risks, and control mechanisms into a Standard Operating Procedure (SOP) remain relatively limited. This research gap indicates the need for an approach that not only identifies risks but also transforms the results of risk analysis into operational mechanisms that can be directly implemented by organizations.

The urgency of this research is underscored by the increasing demand for water infrastructure in Indonesia and the need for improved project delivery performance. With the Indonesian government's commitment to achieving water security and sustainable urban development, the ability to deliver EPC water projects on time and within budget is critical. PT XYZ's experience of schedule delays and cost overruns in previous projects highlights the immediate need for enhanced project control mechanisms. The novelty of this study lies in its comprehensive approach to developing a risk-based SOP that covers all EPC project phases Preparation, Engineering, Procurement, Construction, Commissioning, and Handover and integrates risk management into operational procedures, providing a practical tool that can be directly implemented by organizations.

Based on these conditions, this study aims to develop a risk-based Standard Operating Procedure (SOP) for EPC projects, using a Water Treatment project at PT XYZ as a case study, to improve project schedule and cost performance. The development process was carried out through EPC project activity mapping, stakeholder mapping, risk identification, dominant risk determination, risk response development, and the integration of these elements into a unified and interconnected procedural framework. This study is expected to produce a project control system that is more structured, practical, and aligned with the operational characteristics of EPC projects.

The main contribution of this study lies in the development of a risk-based Standard Operating Procedure (SOP) that functions not only as a procedural document but also as an integration mechanism linking project phases, stakeholders, dominant risks, and risk control strategies. This approach is expected to help organizations focus their resources on activities that have the greatest influence on project performance, improve the effectiveness of process control, and support improvements in schedule and cost performance in EPC projects.

RESEARCH METHOD

Research Design

This study adopted a mixed-methods approach using a case study of a Water Treatment Engineering, Procurement, and Construction (EPC) project at PT XYZ. This approach was selected because the study extends beyond risk identification by integrating risk analysis outcomes into the development of a Standard Operating Procedure (SOP) that can be directly applied to EPC project execution. The research was conducted through a sequential process consisting of EPC project activity mapping, stakeholder identification, risk identification, dominant risk determination, risk response development, and the development of a risk-based SOP.

Study Object and Data Collection

This study was conducted on a Water Treatment Engineering, Procurement, and Construction (EPC) project at PT XYZ. Data were collected using a triangulation approach to enhance the validity of the research findings through four data collection techniques: field observations, project archive analysis, questionnaires, and expert interviews.

Field observations and project archive analysis were used to identify EPC project activities, involved stakeholders, project deviations, and issues encountered during project execution. Subsequently, structured questionnaires were administered to 30 respondents directly involved in EPC project execution to assess the frequency and impact of the identified risks. In addition, expert interviews and validation were conducted with three experts, each having more than ten years of experience in EPC projects, to validate the proposed risk responses and the developed risk-based Standard Operating Procedure (SOP).

Research Stages

The study was carried out through six sequential stages:

1. EPC project activity mapping, aimed at identifying all activities across the different phases of EPC projects,
2. Stakeholder mapping, aimed at identifying stakeholder roles and responsibilities using the Responsibility Assignment Matrix (RACI),
3. Risk identification, aimed at identifying risk events that may affect project schedule and cost performance,

4. Dominant risk determination, aimed at prioritizing risks that require further control measures,
5. Risk response development, aimed at formulating control alternatives that align with the characteristics of the dominant risks,
6. Development of a risk-based Standard Operating Procedure (SOP), aimed at integrating project activities, stakeholders, dominant risks, and risk responses into a unified procedural framework.

Data Analysis

This study employed both qualitative and quantitative data analysis techniques. Qualitative analysis was used to map project activities, stakeholders, risk events, and project control mechanisms. Each risk event was subsequently categorized according to its predominant impact on either schedule performance or cost performance using a cause-and-effect analysis.

Quantitative analysis was performed using a risk matrix based on the combination of risk frequency and risk impact. Furthermore, the Kruskal–Wallis test was applied to evaluate differences in respondents' perceptions across job position, educational level, and work experience groups. Dominant risks were then determined based on predefined risk criteria. The final stage of the study involved expert validation to assess the feasibility, effectiveness, and practicality of implementing the proposed risk responses and the developed risk-based Standard Operating Procedure (SOP), ensuring their alignment with the operational characteristics of EPC projects at PT XYZ.

Research Framework

The research framework consists of three main components: input, process, and output. The research inputs were derived from a literature review, field observations, and project archives. The research process was then carried out through six stages, namely EPC project activity mapping, stakeholder mapping, risk identification, dominant risk determination, risk response development, and the development of a risk-based Standard Operating Procedure (SOP). The final output of the study is a proposed integrated risk-based SOP designed to improve schedule and cost performance in EPC projects at PT XYZ.

RESULTS AND DISCUSSION

EPC Process Mapping

The results indicate that the EPC Water Treatment project at PT XYZ consists of six main phases: Preparation, Engineering, Procurement, Construction, Commissioning, and Handover. Each phase has distinct characteristics, activities, and stakeholder involvement, yet all phases are interdependent and collectively form an integrated project delivery system. Unlike conventional projects, EPC projects exhibit a high degree of interdependence across project phases. The Engineering and Procurement phases serve as key distinguishing features of the EPC approach, as they bridge technical planning and construction execution. Consequently, delays in a single activity may trigger cascading effects on subsequent activities, ultimately affecting project schedule and cost performance.

These findings suggest that EPC project control cannot be managed independently within individual functions but instead requires an integrated approach spanning from project initiation to project handover. Therefore, process mapping serves as a fundamental basis for developing the risk-based Standard Operating Procedure (SOP) proposed in this study.

Table 1 Phases and Key Activities of the Water Treatment EPC Project

No	Phases	Key Activities
1	Preparation	Contract Review, Verification Site Data Verification, Project Execution Planning, Risk Register Development, Baseline Schedule and Cost Establishment
2	Engineering	Engineering Planning, Design Input Review, Design Basis Development, Detailed Engineering Development, Design Review, Engineering Document Control
3	Procurement	Procurement Planning, Vendor Prequalification, Request for Quotation (RFQ), Bid Evaluation & Negotiation, Purchase Order (PO), Vendor Document Review, Fabrication, Inspection & FAT, Delivery & Site Material Control
4	Construction	Site Preparation and Mobilization, Civil & Structural Works, System Installation Works, Testing & Inspection Completion, Punch List Closure
5	Commissioning	Pre-Commissioning, Commissioning, Operational Testing
6	Handover	Project Finalization, Final Handover

Risk Identification

The risk identification process resulted in 104 risk events across all EPC project phases. These risks were identified through a literature review, field observations, project archive analysis, and validation with stakeholders involved in project execution. The findings indicate that risks in EPC projects arise not only from technical aspects but are also influenced by managerial and operational factors. The most frequently identified risks were associated with inadequate stakeholder coordination, delays in decision-making, inconsistencies in technical data, ineffective verification mechanisms, and fragmented document management practices.

Furthermore, the risk characteristics of EPC projects reveal strong interdependencies among project phases. Risks emerging in the early phases of a project may escalate into more significant issues in subsequent phases if not properly controlled at an early stage. These findings suggest that risk management in EPC projects requires an integrated approach throughout the entire project execution life cycle. In addition, this study assigned a single predominant impact to each risk event to maintain analytical focus, ensure consistency in risk mapping, and avoid duplicate classification of risks across multiple categories.

Table 2 Distribution of Risks by Project Phase and Predominant Impact

No	Phases	Risk	Predominant Schedule Impact	Predominant Cost Impact
1	Preparation	17	8	9
2	Engineering	22	10	12
3	Procurement	26	13	13
4	Construction	25	15	10
5	Commissioning	8	5	3
6	Handover	6	5	1
	Total	**104**	**56**	**48**

Dominant Risk Analysis

The findings indicate that not all risks have the same level of priority in achieving project objectives. Of the 104 identified risks, 61 were classified as dominant risks requiring prioritized control measures. These dominant risks comprised 29 risks with predominant impacts on schedule performance and 32 risks with predominant impacts on cost performance. Most of the dominant risks were associated with process control, cross-functional coordination, verification mechanisms, document management, and decision-making.

These findings suggest that control efforts should be focused on risks that exert the greatest influence on project performance. Such prioritization enables organizations to allocate resources more effectively and concentrate their control efforts on activities that contribute most significantly to the achievement of project objectives.

Risk Response Development

The findings indicate that each dominant risk requires a risk response tailored to its underlying characteristics. Rather than establishing entirely new systems, most of the proposed risk responses focus on strengthening existing control mechanisms.

These improvements involve enhancing stakeholder coordination, introducing additional verification mechanisms, strengthening decision-making processes, and improving document control and operational project activities. This approach was adopted because it is considered more practical, more readily implementable, and better aligned with the company's operational conditions.

Furthermore, all proposed risk responses underwent expert validation and were deemed suitable for implementation. These findings suggest that effective risk management is not necessarily aimed at eliminating risks entirely but rather at reducing the likelihood of their occurrence and minimizing their impact on project performance.

Table 3 Dominant Risks and Risk Response Measures

No	Project Activity	Dominant Risks	Risk Response Measures (Additional Mechanism / SOP Revisions)	Response Type
1	Contract Review	Overlooked contract requirements	Contract review checklist	Mitigate
		Inconsistent interpretation of contract provisions		
2	Site Data Verification	Incomplete site data	Site Verification and Clarification Report	Mitigate
		Site conditions inconsistent with available data		
		Impractical design solutions		
3	Project Execution Planning	Uncoordinated project execution	PEP document integration checklist	Mitigate
		Non-compliance with project requirements		
		Non-compliance with quality requirements		
4	Risk Register Development	Inadequate information control	Lessons learned register from similar projects	Mitigate
		Recurring design conflicts		
5	Baseline Schedule and Cost Establishment	Inaccurate duration estimation	Cost and Schedule Baseline Development Checklist	Mitigate
		Misaligned project baselines		
		Incomplete cost baseline		
		Project cost adjustments		

No	Project Activity	Dominant Risks	Risk Response Measures (Additional Mechanism / SOP Revisions)	Response Type
		Cost calculation errors		
6	Engineering Planning	Inappropriate engineer allocation	Engineering manpower planning	Mitigate
7	Design Input Review	Incomplete engineering data	Design Input Control Matrix	Mitigate
		Delays in external data availability		
		Miscommunication among stakeholders		
		Changes in owner requirements		
		Conflicts with existing facilities		
		Inconsistent design interpretation		
		Inconsistencies between FEED and DED		
		Inaccurate engineering assumptions		
8	Design Basis Development	Engineering scope discrepancies	Implementation of a decision gate mechanism for engineering scope changes	Mitigate, Escalate
		Inconsistencies in subsurface data		
		Impractical design concepts		
		Inappropriate design parameters		
9	Detailed Engineering Development	Delays in engineering document preparation	Prioritization of critical documents (long-lead items and construction method requirements)	Mitigate
		Shop drawing inconsistencies		
10	Design Review	Delays in owner approval	Agreed approval timelines and review procedures	Mitigate
		Delays in design decision-making		
		Repeated design revisions		
		Errors in design review		
11	Engineering Document Control	Outdated engineering documents	Engineering Document Distribution List	Mitigate
12	Procurement Planning	Delays in project procurement activities	Procurement Readiness Checklist	Mitigate
		Procurement budget deviations		
13	Vendor Prequalification	Vendor capability mismatch	Vendor Suitability Evaluation Matrix	Mitigate
		Unqualified vendors		
14	Bid Evaluation & Negotiation	Selection based solely on the lowest bid price	Battery limit definition and vendor scope clarification	Mitigate
		Unresolved vendor scope definition		
15	Purchase Order (PO)	Delays in purchase order approval	PO approval timeline requirements and supporting documentation	Mitigate
		Inconsistent interpretation of purchase orders		

No	Project Activity	Dominant Risks	Risk Response Measures (Additional Mechanism / SOP Revisions)	Response Type
16	Vendor Document Review	Delays in vendor document submission	Prioritization of critical documents	Mitigate
17	Fabrication	Delays in material fabrication	Milestone targets for each work stage	Mitigate
		Vendor cash flow constraints		
18	Delivery & Site Material Control	Customs clearance delays	Material handling and storage plan aligned with the construction method	Mitigate
		Delays in critical material delivery		
		Damage to project materials		
		Improper material storage locations		
19	Site Preparation and Mobilization	Delays in heavy equipment mobilization	Equipment readiness requirements, availability plans, inspection plans, and mobilization timelines	Mitigate
		Equipment unavailability		
20	Civil & Structural Works	Inappropriate construction methods	Adjustment of work execution to actual site conditions, including construction methods, resource allocation, and HSE controls	Mitigate
		Differences between actual and planned site conditions		
		Construction rework		
		Occupational safety incidents		
21	Operational Testing	Operational testing disruptions	Contingency procedures for operational disruptions, including PIC assignment, decision authority limits, and testing continuity requirements	Mitigate
22	Final Handover	Delays in final handover completion	Final Handover Readiness Checklist	Mitigate
		Changes in owner representatives (PIC)		
		Prolonged client clarification requests		
		Delays in final payment		

Risk-Based SOP Development

The final outcome of this study was the development of a risk-based Standard Operating Procedure (SOP) that integrates EPC project phases, stakeholders, dominant risks, and risk responses into an integrated procedural framework. The proposed SOP was developed while preserving the company's existing business process structure and focusing on enhancing activities closely associated with dominant risks. These enhancements were implemented through the incorporation of additional verification mechanisms, decision gate mechanisms, supporting documents, checklists, and adjustments to stakeholder roles and responsibilities across selected project activities. This approach resulted in a more systematic control mechanism that can be more readily integrated into existing operational processes.

Compared with the initial SOP, the enhanced SOP functions not only as a guide for project execution but also as an integrated risk control instrument. Consequently, each project activity generates not only operational outputs but is also supported by control mechanisms specifically designed to minimize potential schedule delays and cost overruns.

Expert validation results indicated that the developed risk-based SOP is feasible for implementation as an enhancement to the EPC project execution system at PT XYZ. These findings also suggest that integrating risk management into operational procedures can strengthen an organization's ability to manage risks more proactively throughout the EPC project life cycle.

Activity ID	RISK-BASED STANDARD OPERATING PROCEDURE FOR THE WATER TREATMENT EPC PROJECT												
	Project Activity	STAKEHOLDER											Outputs / Supporting Documents
		X2.A	X2.B	X2.C	X2.D	X2.E	X2.F	X2.G	X2.H	X2.I	X2.J	X2.K	
		Owner	Contractor Head Office	Project Manager	Project Control	Lead Engineering	Lead Procurement	Lead Construction	Lead Quality Control	Lead Comm.	Lead HSE	Vendor	
		START											
X1.A1	Contract Review			A	R	R		R					-Contract Review Checklist -Contract Review Report Basis for Project Execution Plan (PEP) Development
X1.A2	Site Data Verification	C, V		A	R	R		R					-Site Survey Report -Site Verification and Clarification Report
X1.A3	Project Execution Planning	C, V N / Y 1		A	R	C	C	C	C	C	C		-Project Execution Plan (PEP) -PEP Integration Checklist Basis for the development of subsequent documents, including the Engineering Plan, Procurement Plan, and other supporting documents
X1.A4	Risk Register Development	1 C		A	R	R	R	R	R	R	R		-Risk Register Report -Lessons Learned Register from Similar Projects
X1.A5	Baseline Schedule and Cost Establishment		C, V N / Y	A	R	C	C	C			C		-Project Budget Plan (RAP) dan Baseline Schedule (Ms Project) -Cost and Schedule Baseline Development Checklist
X1.B1	Engineering Planning	C		A	C	R	C						Engineering Execution Plan This document includes the deliverables list, document schedule, document control coordination, and engineering manpower planning.
X1.B2	Design Input Review	C		A	C	R 2							-Engineering Input Review -Design Input Control Matrix

Activity ID	Project Activity	X2.A Owner	X2.B Contractor Head Office	X2.C Project Manager	X2.D Project Control	X2.E Lead Engineering	X2.F Lead Procurement	X2.G Lead Construction	X2.H Lead Quality Control	X2.I Lead Comm.	X2.J Lead HSE	X2.K Vendor	Outputs / Supporting Documents
		RISK-BASED STANDARD OPERATING PROCEDURE FOR THE WATER TREATMENT EPC PROJECT											
		STAKEHOLDER											
X1.B3	Design Basis Development	C,V; ◆ (N / Y); ◆ A (N / Y); C,V; ◆ (N / Y)		A; A		2; R; 4; R; 4	DED General; DED General					DED Vendor Spesific 3; DED Vendor Spesific 3	Design Basis Document ◆ A Are there deviations that affect the project scope? *If no, proceed to the DED stage *If deviations are identified, a Technical Query (TQ) must be submitted and approved before proceeding to the DED stage
X1.B4	Detailed Engineering Development			A	C	4; R	C	C	C	C		6	Engineering Documents *Prioritization of critical documents (long-lead items and construction method requirements)
X1.B5	Design Review	C,V; ◆ (N / Y)		A	C	R			C		4	3	Owner approval of engineering documents (4): for General DED (3): for Vendor-Specific DED (chemical addition and filtration systems) *Agreed approval timelines and review procedures
X1.B6	Engineering Document Control			C	A	R	5	I	I	I			Engineering Document Distribution List *Final distribution of engineering documents

RISK-BASED STANDARD OPERATING PROCEDURE FOR THE WATER TREATMENT EPC PROJECT

Activity ID	Project Activity	X2.A Owner	X2.B Contractor Head Office	X2.C Project Manager	X2.D Project Control	X2.E Lead Engineering	X2.F Lead Procurement	X2.G Lead Construction	X2.H Lead Quality Control	X2.I Lead Comm.	X2.J Lead HSE	X2.K Vendor	Outputs / Supporting Documents
X1.C1	Procurement Planning	C		A	C	C	R					1	-Procurement Readiness Checklist -Procurement Execution Plan
X1.C2	Vendor Prequalification	C		A		C	R		C		C	I	-Vendor Suitability Evaluation Matrix -Vendor List
X1.C3	Request For Quotation (RFQ)	I		A		R	C	C	C			3 I	Request For Quotation (RFQ)
X1.C4	Bid Evaluation & Negotiation			A	C	C	R					R 6	-Technical Bid Evaluation -Commercial Bid Evaluation *Battery Limit Definition and Vendor Scope Clarification
X1.C5	Purchase Order (PO)	5 For PO values ≤ X, PO is issued at the project level For PO values > X, PO is issued by Head Office	R, A	A	C		R					I	Purchase Order (PO) Policy at PT XYZ For PO values ≤ X, PO is issued at the project level For PO values > X, PO is issued by Head Office X = IDR 300 million PO approval timelines and supporting documentation requirements
X1.C6	Vendor Document Review	C, V N Y		A	C	C	C		C			R	-Vendor Documents *Prioritization of critical documents
X1.C7	Fabrication			A	C	C	C		C			R	-Fabrication progress reports with milestone targets for each work stage
X1.C8	Inspection & FAT	C, V N Y		A	C	C	C 7		R			R	Inspection Reports and FAT Reports

Activity ID	RISK-BASED STANDARD OPERATING PROCEDURE FOR THE WATER TREATMENT EPC PROJECT												
	Project Activity	STAKEHOLDER											Outputs / Supporting Documents
		X2.A	X2.B	X2.C	X2.D	X2.E	X2.F	X2.G	X2.H	X2.I	X2.J	X2.K	
		Owner	Contractor Head Office	Project Manager	Project Control	Lead Engineering	Lead Procurement	Lead Construction	Lead Quality Control	Lead Comm.	Lead HSE	Vendor	
X1.C9	Delivery & Site Material Control			A	C		7 R	C	C			R 8	-Material Shipment Readiness Checklist -Material Delivery Note -Material Receiving and Issuance Report -Material Handling and Storage Plan aligned with the construction method
X1.D1	Site Preparation and Mobilization	I		A				R			C	1	Equipment Mobilization and Site Preparation *Equipment requirements, availability plans, inspection plans, and mobilization timelines
X1.D2	Civil & Structural Works	C,V N / Y 9		A	C			R	C		C	8 R	Completion of Civil Construction Works *Documented as the basis for progress reporting and readiness assessment for subsequent installation activities *Adjustment of work execution to actual site conditions, including construction methods, resource allocation, and HSE controls
X1.D3	System Installation Works	9 C,V N / Y		A	C	C		R	C	C	C	8 R	Completion of System Installation Works Accompanied by progress reporting and testing readiness indicators
X1.D4	Testing & Inspection Completion	C,V N / Y		A	C	C		R	R	C	C	C	Testing and Inspection Report Testing and inspection completed in accordance with the specifications
X1.D5	Punch List Closure	C		A	C			R	R	C 10	C		Punch List Completion Report All punch list items have been completed, documented, and are ready for the subsequent phase

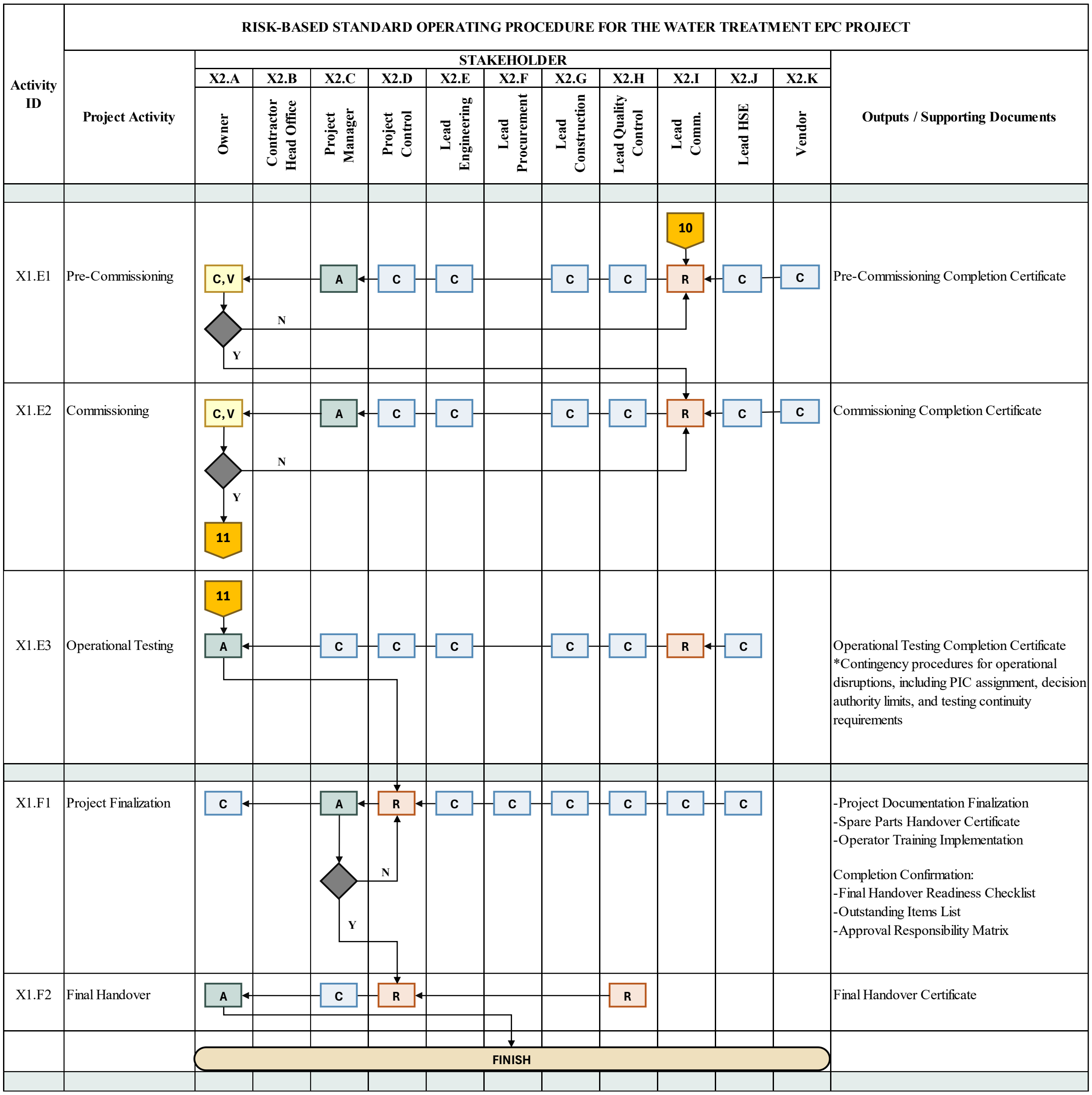

Figure 1 Risk-Based SOP for the Water Treatment EPC Project

To clarify stakeholder involvement within the developed risk-based Standard Operating Procedure (SOP), stakeholder roles were assigned using the Responsibility Assignment Matrix (RACI) with an additional Verification (V) role. In this study, Responsible (R) refers to stakeholders who directly execute an activity, Accountable (A) refers to stakeholders with final authority and overall accountability for the activity outcomes, Consulted (C) refers to stakeholders who provide input and expertise before decisions are made, Informed (I) refers to stakeholders who are kept informed about the progress or outcomes of an activity, and Verification (V) refers to stakeholders responsible for reviewing, validating, and confirming that the activity outputs, documents, or decisions comply with the established requirements before proceeding to subsequent activities.

CONCLUSION

This study successfully developed a risk-based Standard Operating Procedure (SOP) for the Water Treatment EPC project at PT XYZ by integrating project phases, stakeholders, dominant risks, and risk responses into a unified procedural framework. The findings indicate that risks in EPC projects are influenced not only by technical factors but also by process control, coordination, verification mechanisms, document management, and decision-making practices. Of the 104 identified risks, 61 were classified as dominant risks requiring prioritized control measures. The proposed SOP was developed by strengthening existing control mechanisms, resulting in a more structured project execution system that is suitable for implementation to support improvements in schedule and cost performance in EPC projects at PT XYZ. PT XYZ is recommended to implement the risk-based SOP in future EPC projects to evaluate its effectiveness in improving project schedule and cost performance. Future studies may assess the impact of SOP implementation by comparing project performance before and after the adoption of the risk-based SOP.

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