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Risk Management in Petrochemical Industry Development Projects Using WSDOT (Washington State Department of Transportation) Method

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A B S T R A C T

Petrochemical industry development projects are highly complex endeavors characterized by a range of risks that can significantly affect their success. These projects require advanced technologies, specialized materials, and large-scale operations, making effective risk management essential to ensure project success. This study focuses on managing risks in Work Package-2 (WP-2) of Project XYZ, a critical component in Indonesia's petrochemical industry development. The Washington State Department of Transportation (WSDOT) method was applied to identify, assess, and mitigate risks associated with the project. The study highlights various risk categories including construction, technical, health and safety, environmental, social, legal, financial, and supply chain risks. Risk identification was carried out through document analysis, interviews with project management personnel, and on-site observations. Both qualitative and quantitative risk assessments were conducted using risk matrices and Monte Carlo simulations. The findings reveal that the WSDOT method effectively manages risks by providing a structured framework for continuous risk monitoring, risk response strategies, and adaptation to emerging challenges. Key risks with significant financial and schedule impacts were identified, with mitigation strategies focusing on quality control, safety compliance, and project monitoring. This study offers valuable insights into the application of structured risk management methodologies in large-scale construction projects and provides strategic recommendations to enhance risk management practices in petrochemical industry development. The results contribute to improving project resilience, optimizing resource utilization, and ensuring timely and cost-effective project completion.

1. Introduction

The construction of petrochemical industry projects is among the most complex and challenging endeavors in engineering. These projects demand advanced technologies, specialized materials, and large-scale operations, making risk management a crucial aspect to ensure project success. Effective risk management strategies help maintain project timelines, control costs, and achieve the expected quality standards. Project XYZ is a major initiative contributing significantly to Indonesia's petrochemical industry. Among its seven work packages, Work Package-2 (WP-2) is particularly critical as it involves the construction of the Polypropylene (PP) Process and Extrusion Process, essential for polymer production.

The complexity of petrochemical construction projects poses a variety of risks, including technical, financial, and safety risks. Delays in material and equipment delivery, design changes requiring rework, and unskilled labor contribute to project delays, which affect overall performance. To mitigate these challenges, active measures are needed to continuously improve project management and control levels in petrochemical construction management and quality control (Li-hong & Xiang-jun, 2014).

Furthermore, if we review previous research conducted by Keshk, et al., (2018) to find out risk management in construction projects, focusing on the concept of risk, risk management planning, and quantitative and qualitative risk analysis. The study discusses the complexity of modern construction projects that often handle large jobs that can disrupt costs, schedules, and quality. The study uses an analytical approach by integrating quantitative and qualitative techniques to channel risks, as well as risk response strategies that can be applied to minimize their impact. The results of the study indicate the importance of early risk identification and the development of adaptive response strategies, including the creation of mitigation plans that are appropriate to project conditions (Keshk et al., 2018).

One effective method that has been successfully applied in large-scale construction projects is the Washington State Department of Transportation (WSDOT) risk management framework. WSDOT's approach provides a structured methodology for identifying, assessing, and mitigating project risks. Originally developed for transportation infrastructure projects, its principles can be adapted for petrochemical construction due to their shared complexity and risk characteristics.

The WSDOT method emphasizes continuous risk monitoring, structured documentation, and adaptive risk control strategies, which are essential in dynamic construction environments. This is also in line with the need to increase public trust, especially in developing countries, through transparency of information and education, which are important factors in the success of risk control policies (Nie et al., 2020).

This study aims to analyze risk management in the Project XYZ, particularly WP-2, using the WSDOT method. By identifying key risk events, their triggers, and developing mitigation strategies, this research contributes to both theoretical and practical advancements in large-scale construction project risk management. The findings are expected to enhance project resilience, optimize resource utilization, and ensure successful project completion.

2. Related Work

Previous studies have shown that the use of several methods in construction project risk management is effective in solving problems from emerging risks. The table below will briefly display the factors used from each study that has been previously conducted and will show the differences in the factors that will be used in this study.

Table 1. Related Work

Authors	Factors of concern									
	Construction Project Risk Management	Quantitative Approach	Qualitative Approach	Fuzzy AHP	International Projects	Specific Risks (Environmental, Social,	Construction Project Case Study	Survey	Literature Study	WSDOT Method
(Nwaogu et al., 2022)	√							√		
(Soltanzadeh et al., 2022)	√	√		√						
(Malekshah et al., 2022)	√	√								
(Su & Khallaf, 2022)	√								√	
(Younis et al., 2023)	√				√				√	
(Nie et al., 2020)	√					√	√			
(Rudolf & Spinler, 2018)	√					√			√	
(Keshk et al., 2018)	√	√	√						√	
(Christman & Calvi, 2018)							√			
(Martin et al., 2017)	√	√			√			√		
This research	√	√	√				√		√	√

3. Methodology

Research Location and Period

This study was conducted at PT XYZ from September 2024 to November 2024.

Research Stages

The research followed a structured methodology aligned with the study objectives. The main stages included:

1. **Preliminary Study**

Field observations and literature reviews were conducted to understand the theoretical framework of the Washington State Department of Transportation (WSDOT) method for risk management in construction projects.

2. **Problem Identification**

The research problem was formulated based on field observations and data collected through interviews with project management personnel. The identified issues were then translated into specific research objectives.

3. **Data Collection**

Primary Data: Project reports and structured interviews with key project management personnel, including a Project Control Manager, Quality Control Manager, Piping Coordinator, Structure & Mechanical Coordinator, and Superintendent Piping.
Secondary Data: Technical documentation relevant to the project.

4. **Data Processing**

The collected data were analyzed using the WSDOT method through the following steps:

a. **Risk Identification and Categorization:** Risks were classified based on their priority levels.
b. **Risk Assessment:** Both qualitative and quantitative assessments were conducted to evaluate the probability and impact of each risk.
c. **Risk Response Planning and Implementation:** Developing mitigation strategies, establishing contingency plans, documenting and implementing risk response plans, monitoring the execution of mitigation measures. And managing implementation changes.
d. **Risk Monitoring and Evaluation:** Identifying new risks and assessing the effectiveness of risk

responses. Adjusting response plans based on periodic risk reviews. And evaluating overall project risk management performance.

5. **Results and Discussion**

The study assessed the effectiveness of the WSDOT method in managing risks in the XYZ Project, particularly in Work Package-2. The analysis focused on how risk response strategies helped mitigate project risks and identified challenges in implementing the WSDOT approach.

6. **Conclusion and Recommendations**

The final stage involved drawing conclusions based on data analysis and providing recommendations for future projects to enhance risk management strategies in large-scale petrochemical construction.

4. Result and Discussion

Risk Management Plan

The Washington State Department of Transportation (WSDOT) risk management approach provides a structured methodology to identify, assess, and mitigate risks throughout a project's lifecycle. The primary objective is to ensure that the project meets its schedule, budget, and safety standards. The risk management plan includes several categories, such as construction, technical, health and safety, environmental, social and legal, and supply chain risks.

Risk identification was carried out through document analysis, stakeholder interviews, and on-site observations. Risks were assessed using qualitative methods, such as risk matrices, and quantitative techniques, including Monte Carlo simulations to evaluate cost and schedule impacts. The risk response strategies included mitigation through technical preventive measures, risk transfer via insurance or contracts, and risk acceptance with contingency fund preparation.

To ensure effective risk management, continuous monitoring and evaluation were conducted using project management software, monthly risk reports, and compliance audits. The success of WSDOT risk management implementation was measured based on performance indicators such as minimal risk escalation, project completion within the planned schedule, and cost control efficiency.

Risk Identification in the XYZ Project

Data collection for risk identification involved project reports, technical documentation, interviews with project management personnel, and historical data from similar petrochemical projects. Using the WSDOT framework, risks were categorized into:

- **Construction Risks**: Deviations from project plans and cost overruns.
- **Technical Risks**: Design mismatches and poor workmanship.
- **Health and Safety Risks**: Hazards in work activities and non-compliance with safety procedures.
- **Environmental Risks**: Use of hazardous materials and natural disasters.
- **Social and Legal Risks**: Community opposition and contractual disputes.
- **Financial Risks**: Cost fluctuations and funding uncertainties.
- **Supply Chain Risks**: Material delivery delays affecting project progress.

From Table 2. Source of Risk Category there are 7 risk categories and in
Table 3. Source of Risk Event the 7 risk categories have 13 risk events derived from them and from
Table 4. Source of Risk Triggers the 13 risk events are influenced by 31 risk triggers.

Risk Assessment

Both qualitative and quantitative risk assessments were conducted. A probability-impact matrix was used to classify risks into low, medium, and high priority. From the qualitative assessment of the Probability of Risk Events, 7 risk events have high values, namely R.1-1, R.1-2, R.2-1, R.2-2, R.3-1, R.4-1, and R.7-1. In addition, there are 3 risk events with medium values, R.3-2, R.5-1, and R.6-1. There are also 2 risk events with low values, namely R.4-2, and R.5-2. Finally, there is 1 risk event with very low values, namely R.6-2.

Furthermore, from the Qualitative Assessment of the Impact of Risk Events, it is known that there is 1 risk event that has a very high value, namely R.1-1, then there are 9 risk events that have high values, namely R.1-1, R.1-2, R.2-1, R.2-2, R.3-1, R.4-1, R.5-1, R.6-2, and R.7-1. And there are 3 risk events that have moderate values, namely R.3-2, R.5-2, and R.6-1.

Monte Carlo simulations were used to quantify potential financial and scheduling impacts, highlighting critical risks that could lead to cost overruns and project delays. The probability value is obtained through internal simulations conducted by subcontractors to estimate the likelihood of a risk occurring. The minimum risk impact value is the smallest impact that is expected to occur, while the maximum value is the largest impact. The most likely value is taken from the simulation results that show the most frequent risk impact values (Transportation, 2022).

Based on the risk assessment, the risk with the highest expected impact cost value is the increase in costs that exceed the budget, with a value of 0.44 million dollars. And this risk also has the highest expected impact schedule value with a value of 1.72 months.

Risk Mitigation and Management

To manage identified risks, the following strategies were implemented:

- **Mitigation**: Enhancing quality control processes, improving safety compliance, and strengthening project monitoring.
- **Risk Transfer**: Utilizing insurance policies and contractual clauses to allocate risk responsibility.
- **Risk Acceptance**: Establishing contingency funds to absorb unavoidable risks.

By integrating the WSDOT methodology, risk management in the XYZ project was enhanced through systematic monitoring, adaptive response strategies, and continuous improvement measures.

The implementation of WSDOT-based risk management proved effective in mitigating critical risks in the petrochemical construction project. The study highlights the importance of proactive risk identification, structured assessment, and dynamic risk response to ensure project success. The findings contribute to the broader field of risk management in large-scale construction projects, offering insights into best practices for future applications

Table 2. Source of Risk Category

Risk Category	Source
R.1 Construction Risks	(Malekshah et al., 2022)
R.2 Technical Risks	(Martin et al., 2017)
R.3 Health and Safety Risks	(Gholami et al., 2015)
R.4 Environmental Risks	(Soltanzadeh et al., 2022)
R.5 Social and Legal Risks	(Nie et al., 2020)
R.6 Financial Risks	(Malekshah et al., 2022)
R.7 Supply Chain Risks	(Rudolf & Spinler, 2018)

Table 3. Source of Risk Event

Risk Category	*Risk Event*	*Source*
R.1 Construction Risks	R.1-1 Project implementation that does not go according to plan	(Kaur & Singh, 2018)
	R.1-2 Cost increases exceeding budget	(Ashtari et al., 2022)
R.2 Technical Risks	R.2-1 The completion does not match the established design	(Wuni et al., 2021)
	R.2-2 The quality of workmanship does not meet client requirements	(Kamal et al., 2019)
R.3 Health and Safety Risks	R.3-1 Hazards in work activities	(Team, 2024)
	R.3-2 Non-compliance with work methods and work safety procedures	(Enderzon & Soekiman, 2020)
R.4 Environmental Risks	R.4-1 Use of flammable materials and the presence of B3 waste	(Team, 2024)
	R.4-2 Natural disasters such as tsunamis, earthquakes or the like occur.	(Apurva et al., 2020)
	R.5-1 Conflict due to rejection by protesting communities	(Nie et al., 2020)

R.5 Social and Legal Risks	R.5-2 Legal issues regarding contractual issues with other parties	(Younis et al., 2023)
R.6 Financial Risks	R.6-1 Fluctuations in raw material prices due to inflation	(Musarat et al., 2020)
	R.6-2 Uncertainty of financing from investors or fund providers	(Voronina & Steksova, 2020)
R.7 Supply Chain Risks	R.7-1 Supply Chain Delay Disruption	[23]

Table 4. Source of Risk Trigger

Risk Event	***Risk Trigger***	***Source***
R.1-1 Project implementation that does not go according to plan	R.1-1-1 Failure in schedule management	[18]
	R.1-1-2 Supply Chain Constraints	[24]
	R.1-1-3 Changes in Scope of Work	[25]
R.1-2 Cost increases exceeding budget	R.1-2-1 Schedule Delays Impacting Costs	[26]
	R.1-2-2 Failure in Financial Risk Management	[27]
	R.1-2-3 Lack of Control over Subcontractors	[28]
R.2-1 The completion does not match the established design	R.2-1-1 Limitations of Quality Control	[18]
	R.2-1-2 Delay in Providing Materials or Equipment According to Specifications	[29]
R.2-2 The quality of workmanship does not meet client requirements	R.2-2-1 Time Constraints and Tight Schedules	[18]
	R.2-2-2 Limited Competence and Skills of the Workforce	[30]
	R.2-2-3 Lack of Effective Quality Control System	[31]
R.3-1 Hazards in work activities	R.3-1-1 Lack of HSE Supervision in the Field	[32]
	R.3-1-2 Poorly Maintained Equipment and Machinery	[33]
	R.3-1-3 Safety Procedures Not Executed Properly	[18]
R.3-2 Non-compliance with work methods and work safety procedures	R.3-2-1 Pressure to Meet Time and Productivity Targets	[34]
	R.3-2-2 Lack of Strict HSE Supervision	[35]
R.4-1 Use of flammable materials and the presence of B3 waste	R.4-1-1 Lack of Risk Control System for Hazardous Materials	[18]
	R.4-1-2 Non-compliance with Safety Regulations and Standards	[36]
	R.4-1-3 Poor waste management	[37]
R.4-2 Natural disasters such as tsunamis, earthquakes or the like occur.	R.4-2-1 Failure in Implementing Disaster Mitigation Systems	[18]
	R.4-2-2 Climate Uncertainty and Extreme Weather Change	[38]
R.5-1 Conflict due to rejection by protesting communities	R.5-1-1 Lack of Engagement and Communication with Local Communities	[39]
	R.5-1-2 Limitations of Social Conflict Management	[40]
R.5-2 Legal issues regarding contractual issues with other parties	R.5-2-1 Ambiguity or Vagueness in Contract Clauses	[41]
	R.5-2-2 Late Payment or Payment Settlement	[18]
	R.6-1-1 Dependence on External Supply	[42]

R.6-1 Fluctuations in raw material prices due to inflation	R.6-1-2 Increase in Transportation and Logistics Costs	[43]
R.6-2 Uncertainty of financing from investors or fund providers	R.6-2-1 Schedule Delay or Cost Overrun	[18]
	R.6-2-2 Global and National Economic Conditions	[44]
R.7-1 Supply Chain Delay Disruption	R.7-1-1 Dependence on a Single Supplier or Foreign Supplier	[45]
	R.7-1-2 Material Market Instability	[18]

5. Conclusion

The This study highlights the critical role of risk management in petrochemical construction projects, particularly in identifying, assessing, and mitigating risks using the Washington State Department of Transportation (WSDOT) method. Seven primary risk categories were identified, including construction, technical, occupational health and safety (K3), environmental, social and legal, financial, and supply chain risks. From the risk identification process, 13 risk events and 31 key triggers were determined, spanning technical, managerial, financial, and environmental uncertainties.

The risk assessment results indicate that, in terms of probability, seven risks were categorized as "high," three as "medium," two as "low," and one as "very low." Meanwhile, in terms of impact, one risk was classified as "very high," nine as "high," and three as "medium." Quantitative analysis further revealed that the highest financial impact risk amounted to 0.21 million USD, while the highest schedule impact risk could cause a delay of up to 1.72 months.

To manage these risks, specific mitigation strategies were implemented. The highest financial impact risk was addressed through renegotiations with vendors, requiring an estimated cost of 0.21 million USD and a mitigation period of 1.03 months. Meanwhile, the highest schedule impact risk was mitigated through re-planning and additional work documentation beyond the initial scope, incurring a mitigation cost of 0.16 million USD and a duration of 1.72 months.

For risk control, deviations from the project plan were managed through re-planning, progress monitoring, and root cause analysis. To mitigate cost escalation risks, budget monitoring, contingency fund evaluation, material price analysis, and vendor negotiations were conducted. These strategies aim to ensure project success by effectively managing risks that could significantly impact project costs and timelines.

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