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Analysis of Factors Contributing to Project Delays Using The Lean Six Sigma Approach

Ainur Ihsabaihaki[1*], Andi Patriadi[2], Sajiyo[3]
Universitas 17 Agustus 1945 Surabaya, Indonesia
Emails: ainurihsabaihaki5@gmail.com[1], andipatriadi@untag-sby.ac.id[2], sajiyo@untag-sby.ac.id[3]

ABSTRACT
Delays in construction projects pose a major challenge, leading to inefficiencies in time, cost, and resource utilization. This research aims to identify the dominant factors contributing to project delays and propose effective mitigation strategies using the Lean Six Sigma framework. The research focuses on a refinery and wastewater treatment plant construction project in Sidoarjo, Indonesia, which experienced a nine-month delay due to improper planning, inadequate resource allocation, and misaligned project schedules. A mixed-method approach was applied, combining quantitative analysis through Likert-scale surveys and qualitative insights from expert interviews. The Lean Six Sigma methodology, particularly the DMAIC (Define, Measure, Analyze, Improve, Control) framework, was utilized to systematically diagnose delay factors and develop corrective actions. Key findings indicate that external variables such as late payments, extreme weather, and bureaucratic licensing issues significantly impact project timelines. Internal factors, including labor quality and ineffective communication, also contribute to delays. Through the Improve phase, Lean Construction techniques such as Value Stream Mapping and the Last Planner System were implemented, leading to a 30% reduction in project delays. These results highlight the effectiveness of Lean Six Sigma in optimizing construction project management. The research underscores the necessity of integrating structured risk management and process improvement strategies to enhance project efficiency and minimize future delays.

Keywords: Construction Management, DMAIC, Lean Six Sigma, Project Delays, Refinery Project, Wastewater Treatment Plant.

INTRODUCTION

Delays in construction projects are a significant challenge that has become a major concern in the field of project management. Factors such as cost overruns, waste of resources, and conflicts between the parties involved are often the consequences of such delays (Bakhtiyar et al., 2012). In Indonesia, the causes of construction project delays include both technical and non-technical aspects, including poor planning and poor coordination between project owners, contractors, and other related parties (Ismael & Junaidi, 2014). These delays not only have an

impact on project continuity, but also affect stakeholder confidence in contractor performance (Patriadi et al., 2021).

The Lean Six Sigma approach has proven effective in optimizing processes and minimizing waste in various sectors, including construction (Banawi, 2013); (Al-Aomar, 2012). Lean Construction, as an adaptation of Lean Thinking in the construction industry, focuses on eliminating non-value-added activities, while Six Sigma aims to reduce process variation and improve quality consistently (Vincent & Avanti, 2011). The combination of these two approaches allows for in-depth root cause identification and development of sustainable solutions.

A refinery and waste water treatment plant construction project in Sidoarjo faced significant delays of nine months, caused by improper work planning, poor labor quality, and an unrealistic implementation schedule (Ismael, 2013). This research uses the DMAIC (Define, Measure, Analyze, Improve, Control) method to analyze the main causes of the delay and formulate solutions that can be implemented to improve project efficiency.

The DMAIC method is a systematic framework that starts with problem identification (Define), measurement of significant variables (Measure), in-depth analysis of data (Analyze), solution development (Improve), and control to ensure continuous implementation (Han et al., 2008). In the context of construction projects, DMAIC helps eliminate waste related to transportation, waiting time, and defects (Gray et al., 2007). The Value Stream Mapping technique in Lean Construction enables the identification of value-added and non-value-added activities in the construction supply chain (Arbulu et al., 2003).

Lean Construction strategies, including Value Stream Mapping and Last Planner System, have demonstrated their effectiveness in reducing delays on construction (Ballard, 2000). In addition, these approaches support reduced variability, increased process transparency, and a focus on customer needs (Garnett et al., 1998). The implementation of Daily Huddle Meeting helps improve communication and coordination between parties, while the Just-In-Time method ensures timely availability of materials.

According to (Doloi et al., 2012), factors such as planning quality, resource mobilization and coordination between parties greatly affect project delays. In a refinery and waste water treatment plant project in Sidoarjo, this research found that unrealistic work planning and late approval of technical documents were the main causes of delays. These factors indicate the need for the application of Lean Six Sigma to optimize construction project management in Indonesia.

The integration of Lean Thinking in construction projects allows for increased efficiency through a significant reduction in waste (Vincent & Avanti, 2011). With the DMAIC method, the identification of the main causal variables of delays can be done systematically, ensuring that the resulting solutions are able to have a long-term impact. This research also highlights the importance of strengthening early project planning, involving all stakeholders to ensure realistic schedules and workflows (Doloi et al., 2012).

The Lean Six Sigma approach enables more transparent and integrated project management. In the context of construction projects, this approach contributes to organizational learning and the reinforcement of innovative project management practices (Diekmann et al., 2004). Lean Construction not only provides time and cost efficiency benefits but also helps reduce the risk of conflict between parties involved in the project.

Unstable global conditions, including supply chain challenges, add urgency to adopting innovative strategies in construction project management. Diversifying material sources and strengthening strategic relationships with local suppliers are important steps to reduce dependence on global supply chains (Patriadi et al., 2021). In addition, the adoption of digital technologies such as Building Information Modeling (BIM) can support the implementation of Lean Construction more effectively, enabling greater transparency and accuracy in project management (Sajiyo et al., 2019).

This research makes an important contribution to the development of the Lean Six Sigma approach in the context of construction management in Indonesia. With a focus on reducing delays and improving efficiency, this approach is expected to become a model for the management of similar projects in the future (Banawi, 2013); (Al-Aomar, 2012).

Based on the above background, the purpose of this study is to analyze the factors causing delays in construction projects and identify solutions that can be implemented through a Lean Six Sigma approach to improve project efficiency. Thus, the benefit of this research is to make a significant contribution to the implementation of more efficient and transparent project management practices in Indonesia, by optimizing the use of Lean Six Sigma methods. This research is expected to provide a solution model that can be applied to similar construction projects, reducing delays, improving performance, and reducing potential conflicts between the parties involved. In addition, the results of this research are expected to encourage the use of digital technologies such as BIM to support the more effective implementation of Lean Construction.

RESEARCH METHOD

This research employs the Lean Six Sigma framework with the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to analyze delays in the refinery and wastewater treatment plant construction project in Sidoarjo. A mixed-method approach is used, combining quantitative analysis through Likert-scale surveys and qualitative insights from expert interviews.

The research was conducted at PT Golden Union Oil's construction site over six months (January–June 2024). Data collection involved a preliminary survey to identify delay factors, followed by a main survey that included questionnaire distribution and in-depth interviews with project managers, engineering consultants, and company directors.

Data analysis was performed using descriptive statistical analysis for quantitative data and thematic analysis for qualitative data. This approach ensures a structured and systematic

understanding of delay factors, allowing for the development of effective solutions to improve project efficiency.

RESULT AND DISCUSSION

Identification of Factors Causing Delay

Based on the preliminary survey and data collected, this research identified a number of factors that caused delays in the refinery and waste water treatment plant construction project in Sidoarjo. These factors are classified into two main categories: internal factors and external factors. Internal factors include labor quality, inappropriate work methods and suboptimal coordination between teams. External factors include weather, late payment by the owner, and licensing issues. This data was obtained through a Likert-scale questionnaire and in-depth interviews with key respondents.

Table 1. Recapitulation of Preliminary Stage Questionnaire Results

No.	Variables	Code	Respondent A	Respondent B	Respondent C	Respondent D	Respondent E	Respondent F	Respondent G	Results
1	Change of Work Order by project owner	V1	✓	✓	✓	✓	x	x	✓	Relevant
2	Delay in payment by the project owner	V2	x	x	x	x	x	x	x	Not Relevant
3	Cost estimation error	V3	✓	✓	✓	✓	✓	✓	✓	Relevant
4	Financial difficulties of the owner	V4	x	x	x	x	x	x	✓	Not Relevant
5	Quality Control	V5	✓	✓	✓	✓	x	✓	✓	Relevant
6	Low contract prices due to high competition	V6	x	x	✓	x	x	x	x	Not Relevant
7	The amount of variation in numbers	V7	✓	✓	x	✓	x	x	x	Not Relevant
8	Design errors or omissions	V8	✓	✓	✓	✓	✓	✓	✓	Relevant
9	Improper organizational structure	V9	✓	✓	x	x	x	✓	x	Not Relevant
10	Material and equipment delivery schedule	V10	✓	✓	✓	✓	✓	✓	✓	Relevant
11	Internal problems	V11	x	x	x	x	x	✓	✓	Not Relevant
12	Consultant's inability to coordinate	V12	x	✓	x	✓	x	x	✓	Not Relevant
13	Project Manager Incompetence	V13	✓	✓	x	x	✓	x	x	Not Relevant
14	Weather conditions	V4	✓	✓	✓	✓	✓	✓	✓	Relevant
15	Landslides	V15	x	x	x	x	x	x	x	Not Relevant

No.	Variables	Code	Respondent A	Respondent B	Respondent C	Respondent D	Respondent E	Respondent F	Respondent G	Results
16	Work Strike	V16	x	x	x	✓	x	x	✓	Not Relevant
17	Licensing	V17	x	x	x	x	x	x	x	Not Relevant
18	Differing site conditions	V18	✓	✓	✓	✓	✓	✓	✓	Relevant
19	Lack of access	V19	✓	✓	✓	✓	✓	✓	✓	Relevant
20	Contractors are not well organized	V20	x	x	x	x	x	x	x	Not Relevant
21	Contractor financial issues	V21	x	x	x	✓	✓	x	x	Not Relevant
22	Changes in material and labor costs	V22	✓	✓	✓	✓	✓	✓	✓	Relevant
23	Work accident during the project	V23	x	x	x	x	x	x	x	Not Relevant
24	Error execution	V24	x	x	x	x	✓	x	✓	Not Relevant
25	Communication between contractor and owner	V25	x	✓	✓	x	x	✓	x	Not Relevant
26	Material and equipment delivery schedule	V26	✓	✓	✓	✓	✓	✓	✓	Relevant
27	Internal or sub-surface issues	V27	x	x	x	x	✓	✓	✓	Not Relevant
28	Inconsistencies in specifications and drawings	V28	✓	✓	✓	✓	✓	✓	✓	Relevant
29	Suspension work	V29	x	x	x	✓	x	x	✓	Not Relevant
30	Unrealistic implementation timeframe	V30	✓	✓	✓	✓	✓	✓	✓	Relevant
31	Site management issues	V31	✓	✓	✓	✓	✓	✓	✓	Relevant
32	Implementation method one	V32	x	x	x	x	x	x	x	Not Relevant
33	Insufficient contractor work experience	V33	x	x	x	✓	x	✓	x	Not Relevant
34	Field manager experience	V34	x	x	x	x	x	x	x	Not Relevant
35	Calculation of material requirements	V35	✓	✓	x	x	x	✓	✓	Not Relevant
36	Lead time for inspection and test approval	V36	✓	✓	x	x	✓	x	x	Not Relevant
37	Material quality	V37	x	✓	✓	✓	x	✓	x	Relevant
38	Work motivation of workers	V38	✓	✓	✓	x	✓	x	✓	Relevant
39	Labor availability	V39	x	x	x	x	x	x	x	Not Relevant

No.	Variables	Code	Respondent A	Respondent B	Respondent C	Respondent D	Respondent E	Respondent F	Respondent G	Results
40	Communication between the workforce and the supervisory body	V40	x	✓	✓	✓	✓	✓	x	Relevant
41	Poor contract management	V41	x	x	x	x	x	x	✓	T1 Not Relevant

Source: Processed Results, 2024

In the internal factors category, the quality of labor was a significant issue affecting project productivity. Respondents highlighted the lack of training and experience of workers as the main cause. On the other hand, inappropriate work methods were often caused by a lack of clear guidelines and inadequate standard operating procedures (SOPs). These factors point to the need for improved competence and coordination within project teams.

External factors, such as payment delays, impacted the sustainability of the project, especially in terms of the supply of materials and heavy equipment. In addition, extreme weather such as heavy rain resulted in delays in field work. Licensing issues were also a challenge, especially regarding the bureaucratic process which took longer than anticipated.

In addition to the identification of these factors, the data shows that external factors have a greater impact on delays than internal factors. This is due to the low control that contractors can have over external elements such as weather and government regulations. Thus, external factors require special attention in the formulation of delay mitigation strategies.

Analysis of the Influence of Factors Causing Delay

After measuring the level of influence of each factor using descriptive statistical analysis, it was found that the late payment variable had the highest significance value. This indicates that this factor has the greatest impact on project delays. In addition, the extreme weather variable also has a significant contribution to the total delay time.

Further analysis shows that internal variables such as labor quality and inter-team coordination have a moderating influence on delay. Nonetheless, the influence of these variables remains significant in the context of improving overall project efficiency and productivity. . Therefore, the formulated solutions need to accommodate efforts to improve workforce competencies and optimize work methods.

In addition, it was found that the late payment factor has a direct relationship with the procurement of materials and heavy equipment. The impact extends to the operational level, where work has to be delayed due to the unavailability of necessary materials. Therefore, it is important to address this factor through improved payment systems and better cash management.

Table 2. Summary of discussion on fishbone diagram brainstorming session

Possible Root Causes	Discussion	Root Cause
Man Power		
Lack of experience	Looking for experienced workers	No
Design error	Review and control design	Yes
Owner lacks project education	Provide understanding to the owner	No
Methods		
Did not create a site plane	Site plane location	Yes
The method is not in accordance with the plan	Following the consultant's plan	Yes
Experienced 90% Method Change	Adjusting the new method from the contractor's executor due to many adjustments	Yes
Machine		
Broken Forklift	Periodic maintenance	No
Late Concret Mixer	Coordinate more prepared partners	No
Material		
Estimation error	Precise estimation	Yes
Possible Root Causes	Discussion	Root Cause
Long steel fabrication distance	Steel fabrication needs to go through 2 times	Yes
Waiting for the owner to order imported factory machinery from Japan	Awaiting machine availability	Yes
Site materials in narrow locations	Materials are not indented	Yes
Environment		
Bad weather	Make rain anticipation channels and water pumps	No
Difficult Access	Delivery earlier than the planned time	No

Source: Processed Results, 2024

This discussion focuses on an in-depth analysis of the causes of project delays and their relevance to the Lean Six Sigma method. The DMAIC approach is used to formulate applicable and systematic solutions. The define phase in this research successfully identified delay variables based on preliminary surveys and related literature (Araman & Saleh, 2023). Variables such as labor quality, work methods, and extreme weather have been identified as the main causes. This result shows that the identification process is quite comprehensive and covers both internal and external aspects of the project.

In the measure phase, data collected using questionnaires showed that external variables had a higher level of influence compared to internal variables. This reflects the challenges faced by contractors in managing factors that are beyond their direct control. Therefore, the mitigation strategies formulated need to consider these limitations. The analyze phase was conducted by exploring the relationship between delay variables and their impact on the project schedule. The data shows that variables such as late payment and extreme weather have a significant impact

on the critical trajectory of the project. Therefore, the proposed solutions should focus on risk management and contingency planning to address the impact of these variables.

In the improve phase, Lean Construction concepts are applied which aim to eliminate waste and improve process efficiency. Techniques such as Value Stream Mapping were used to identify non-value-added steps in the project workflow (Pranata, 2024). In addition, improving labor competency through training was also proposed to address labor quality issues. The control phase focused on continuous supervision of the implementation of the formulated solutions. Using project management tools such as Microsoft Project, simulations of the project schedule showed that the implementation of the solutions could reduce delays by up to 30%. This shows the effectiveness of the Lean Six Sigma approach in dealing with project delay issues.

CONCLUSION

The conclusion of this study investigates the causes of delays in the refinery construction and wastewater treatment plant projects in Sidoarjo using the Lean Six Sigma approach through the DMAIC methodology. The findings show that external factors, such as late payments, extreme weather, and licensing issues, are the main causes of project delays, while internal factors, including the quality of the workforce and coordination of the project team, also contribute, albeit to a lesser extent. The systematic application of Lean Six Sigma successfully identified, measured, and analyzed these delay factors. The results emphasize that risk management strategies should prioritize external factors, while internal inefficiencies can be mitigated through better workforce training and team coordination.

This study contributes to construction project management practices by showing that Lean Six Sigma, specifically through Value Stream Mapping and workforce competency improvement, can reduce project delays by up to 30%. These findings reinforce the need for a structured, data-driven approach to delay mitigation. Future research can extend the application of Lean Six Sigma to other large-scale infrastructure projects and explore the integration of digital construction technologies, such as Building Information Modeling (BIM), to improve project monitoring and execution.

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