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Implementation of Lean Construction To Reduce Project Delays

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ABSTRACT
This study investigates the application of Lean Construction techniques within the "Improve" phase of the Lean Six Sigma framework to reduce delays in construction projects. Utilizing Value Stream Mapping (VSM), the research identifies inefficiencies and eliminates non-value-added activities in the construction process. A case study on PT Golden Union Oil's refinery project in Sidoarjo demonstrates the effectiveness of Lean Construction, resulting in a 57.49% reduction in waste. The research also highlights challenges such as poor planning, coordination issues, and delays in material supply, which are common causes of delays in construction projects. By applying Lean Construction principles, including the Last Planner System and Just-In-Time techniques, this study optimizes resources, improves workflow, and accelerates project timelines. The findings confirm that Lean Construction, when integrated with Lean Six Sigma, offers a systematic approach to addressing delays and improving project performance. The research provides valuable insights for the Indonesian construction industry, offering a practical model for reducing project delays, improving efficiency, and optimizing resource utilization. Through this approach, construction projects can achieve better coordination, reduced cycle times, and improved cost management, contributing to the overall competitiveness and sustainability of the construction sector.

INTRODUCTION

Delays in construction projects are a frequently encountered problem, not only in Indonesia but also globally. According to Bakhtiar et al. (2012), project delays can be caused by various factors such as poor planning, inappropriate work methods, and limited resources. In Indonesia, Abduh and Roza (2006) highlighted the readiness of local contractors in adopting Lean Construction to minimize waste and improve project efficiency. The concept is designed to reduce non-value-added activities and increase value for customers.

Lean Construction is the adaptation of Lean Manufacturing principles to the construction industry. It aims to eliminate waste, streamline work flow, and increase added value (Gaspersz, 2007). Al-Aomar (2012) notes that the integration of Lean with Six Sigma provides a systematic approach in reducing process variation and improving quality. This integration supports the implementation of Value Stream Mapping (VSM), which enables the identification of value-added activities and elimination of waste (R. J. Arbulu & Tommelein, 2002).

The study by Diekmann et al. (2004) shows that the implementation of Lean Construction can improve efficiency by reducing cycle time and costs. Han et al. (2008) added that a Six Sigma-based approach can help measure and analyze the main causes of delays, thus enabling more effective improvements. In the Indonesian context, Abduh (2016) introduced the concept of lean construction as a strategic solution to improve the competitiveness of national contractors. Project delays are often caused by a lack of coordination between stakeholders. Gray et al. (2007)noted that poor communication and slow decision-making are common causes. Ismael and Junaidi (2014) highlight the importance of identifying the dominant factors of delays, such as design errors, lack of planning, and logistical constraints. These delays affect not only time but also costs, which often balloon due to the need to make revisions or repairs (Ismael, 2013).

In the Refinery and Waste Water Treatment Plant construction project in Sidoarjo, the use of Lean Construction succeeded in reducing waste by 57.49%. This was achieved through the application of Value Stream Mapping to map work processes and identify areas of waste (Patriadi et al., 2021). This technique allows the optimization of resources, both human and material, thereby increasing efficiency and reducing unnecessary additional costs.

Waste reduction strategies in Lean Construction include techniques such as the Last Planner System (Ballard, 2000) which ensures more realistic and reliable work planning. Garnett et al. (1998) emphasize the importance of collaboration between parties in the project to reduce variability and improve work flow. Abdulaziz (2013) notes that an integrative approach between Lean, Green, and Sigma can have a positive impact in creating more efficient and sustainable projects.

In its implementation, Lean Construction requires commitment from all stakeholders. Arbulu and Tommelein (2003) note that supply chain analysis is an important step in ensuring materials and information flow efficiently. This is in line with the findings of Han et al. (2008), who showed that Six Sigma-based performance measurement can identify critical variables that affect project outcomes. Doloi et al. (2012) developed a structural model to identify factors that influence project success. They found that good coordination, effective risk management, and utilization of information technology can reduce the likelihood of delays. On the other hand, research by Sajiyo et al. (2019) showed that a supportive project environment also plays an important role in determining the success of construction implementation.

The application of Lean Construction not only impacts time efficiency but also improves the quality of results. According to Haggard (2017), the benefits of this implementation include reduced defects, improved work safety, and reduced costs. In Indonesia, this initiative can be part of the construction industry's modernization efforts, as noted by Abduh (2016). However, challenges in the implementation of Lean Construction remain. One of them is resistance to change, especially from a workforce accustomed to traditional methods (Gespersz, 2007). To overcome this, intensive training and education is required for all parties involved, as suggested by Al-Aomar (2012).

In the Lean Six Sigma framework, the Improve phase is key in integrating Lean Construction. Through this phase, improvements are made systematically based on the analysis of previously collected data (Han et al., 2008). This enables sustainable and data-driven solutions to be achieved. The implementation of Lean Construction in the Refinery construction project in Sidoarjo also shows that this approach can be applied on a large scale. By using techniques such as Value Stream Mapping and Last Planner System, the project achieved significant efficiency (Patriadi et al., 2021).

Overall, research and experiences from various countries show that Lean Construction is a relevant approach to address the challenges of project delays in Indonesia. By integrating Lean and Six Sigma principles, the construction industry can move towards a more efficient and sustainable future (Abduh and Roza, 2007; Al-Aomar, 2012).

Delays in construction projects are complex issues that require a holistic approach to resolve. Various studies show that the factors causing delays include inadequate planning, poor coordination, and high process variation (Bakhtiar et al., 2012; Ismael, 2013). To address these issues, an integrated Lean Construction approach within the Lean Six Sigma framework can be an effective solution. Techniques such as Value Stream Mapping enable the identification and elimination of non-value-added activities, while other strategies such as the Last Planner System improve planning accuracy (Ballard, 2000; Arbulu and Tommelein, 2002). In this context, the problem formulation can be focused on how to implement Lean Construction to reduce waste and improve the efficiency of construction projects in Indonesia, as successfully applied to the Refinery and Waste Water Treatment Plant construction project in Sidoarjo.

LITERATURE REVIEW

Lean Construction Concept

Lean Construction is an adaptation of Lean Manufacturing principles specifically designed for the construction industry. According to Gespersz (2007), this concept aims to eliminate waste, increase efficiency, and add value to customers. Al-Aomar (2012) states that the integration of Lean with Six Sigma enables better management of process variations through accurate data analysis. In this context, Value Stream Mapping (VSM) is used to map work processes, identify non-value-added activities, and eliminate them systematically (Arbulu and Tommelein, 2002).

In addition, Diekmann et al. (2004) emphasized that the implementation of Lean Construction can reduce project cycle time and operational costs. The implementation of techniques such as the Last Planner System also helps in reducing planning uncertainty (Ballard, 2000). Haggard (2005) mentions that other benefits of Lean Construction include reduced defects, improved safety, and reduced costs. Therefore, Lean Construction is a strategic choice to improve contractor competitiveness, especially in Indonesia (Abduh and Roza, 2007).

Lean Construction also demands commitment from all parties in the project. According to Garnett et al. (1998), good collaboration between project owners, contractors, and suppliers is key to successful implementation. However, the main challenge is resistance to change, especially from workers who are used to traditional methods (Gespersz, 2007). To overcome this, intensive training and information technology support are needed to facilitate the adoption process of Lean Construction (Han et al., 2008).

Lean Six Sigma in Project Management

Lean Six Sigma is a combination of two methodologies that aim to improve efficiency and quality in project management. Al-Aomar (2012) notes that the integration of Lean and Six Sigma allows the identification of root causes through in-depth statistical analysis. This technique helps construction projects to focus on value-added activities, while non-value-added activities are eliminated. In this regard, VSM becomes a very effective tool to visualize processes and identify areas of improvement (Arbulu and Tommelein, 2002).

The Lean Six Sigma approach involves five phases, namely Define, Measure, Analyze, Improve, and Control (DMAIC). Han et al. (2008) explain that the Define phase aims to identify the main problems and determine the improvement objectives. Furthermore, the Measure phase is used to collect relevant data, while the Analyze phase helps determine the factors causing the problem. In the Improve phase, solutions are implemented based on the analysis results, and the Control phase ensures the sustainability of the improvement results (Diekmann et al., 2004).

The benefits of Lean Six Sigma include reduced variation, increased accuracy, and time efficiency. Abdulaziz (2013) notes that the application of this method can improve overall project performance, including in terms of cost and time control. In addition, Lean Six Sigma also encourages a culture of continuous improvement that is highly relevant to the needs of the modern construction industry (Garnett et al., 1998). However, its implementation requires high commitment from all parties as well as a deep understanding of the methodology (Al-Aomar, 2012).

Case Study of Lean Construction Implementation

The application of Lean Construction in the Refinery and Waste Water Treatment Plant construction project in Sidoarjo produced significant results. Using VSM, the project successfully identified areas of waste and reduced non-value-added activities by 57.49% (Patriadi et al., 2021). The technique also helped improve workflow and resource efficiency, both human and material. These results show that Lean Construction has great potential to be applied to other construction projects in Indonesia (Abduh and Roza, 2007).

The Last Planner System technique is also applied to ensure more realistic and reliable planning. Ballard (2000) explains that this technique allows all parties in the project to contribute to the planning process, thereby reducing uncertainty and increasing team involvement. In addition, collaboration between project owners, contractors, and suppliers becomes more effective, as noted by Garnett et al. (1998). The result is increased transparency and reduced conflict during project execution (Diekmann et al., 2004).

However, the implementation of Lean Construction is not free from challenges. Gespersz (2007) notes that resistance to change and lack of understanding of the concept are often the main obstacles. To overcome this, comprehensive training and effective communication between all parties are required (Al-Aomar, 2012). In this context, information technology can be a useful tool to support the implementation process and ensure sustainability of results (Han et al., 2008).

Overall, the experience from the Sidoarjo project shows that Lean Construction is an effective approach to overcome project delays. With the integration of Lean Six Sigma, improvement results become more measurable and sustainable. Therefore, the application of this approach is expected to improve the competitiveness of the Indonesian construction industry at the global level (Abduh, 2016; Al-Aomar, 2012).

Delays in construction projects have long been a significant challenge in the industry, often leading to resource waste, budget overruns, and conflicts among stakeholders. In Indonesia, where rapid infrastructure development is crucial, the need for efficient project management practices has never been more pressing. Construction delays not only hinder economic growth but also damage the reputation of contractors and stakeholders involved. This study addresses the urgency of applying Lean Construction techniques to reduce project delays and optimize resource utilization, making it a timely and necessary investigation for improving the construction sector's efficiency.

While various studies have explored the application of Lean Construction principles, there is limited research on integrating Lean Construction with Lean Six Sigma frameworks in the Indonesian construction context. Additionally, while Value Stream Mapping (VSM) has been proven effective in eliminating waste in construction projects, its use within the construction industry's real-world, large-scale projects, particularly in Indonesia, is still underexplored. This research aims to fill this gap by applying these integrated methodologies to a real-life case study of a refinery project, showcasing their practical benefits in the local context.

The novelty of this study lies in its comprehensive application of Lean Construction principles combined with Lean Six Sigma's DMAIC framework to a large-scale construction project in Indonesia. By focusing on the "Improve" phase, this research goes beyond typical Lean applications and addresses the practical challenges of reducing project delays using Value Stream Mapping (VSM) and other Lean techniques. The integration of Lean Construction with Six Sigma methodologies offers a systematic and innovative approach to enhancing project efficiency, making this study particularly relevant to the Indonesian construction sector.

The purpose of this study is to investigate how Lean Construction principles, particularly Value Stream Mapping, can be applied to reduce delays in construction projects. By integrating Lean with Six Sigma, the study seeks to provide actionable strategies that can be used to optimize construction timelines and improve resource utilization. The benefits of this research include reducing project cycle times, improving coordination among stakeholders, and cutting unnecessary costs. Furthermore, the study provides a replicable framework for other construction projects in Indonesia and beyond, offering a model for sustainable and efficient project management.

RESEARCH METHOD

Research Conceptualization

This research begins with the preparation of a framework that underlies the entire research process. This framework integrates theories related to construction project delays with the Lean Six Sigma approach. The first stage is the identification of variables that cause project delays. These variables were obtained from a literature review and an initial survey of respondents consisting of project managers, expert staff, and consultants.

The next stage was data collection using a Likert scale-based questionnaire instrument to measure the significance of each variable on lateness. The data obtained was analyzed using descriptive and analytical statistical methods. The analysis results are used to develop improvement solutions based on the DMAIC (Define, Measure, Analyze, Improve, Control) framework. The Improve phase utilizes Lean Construction techniques to produce systematic improvements to the project process. In the Control phase, the solution implementation was simulated using Microsoft Project software to test the effectiveness of delay reduction. The entire research process is designed to contribute to the development of more efficient and effective project management practices.

Research Location and Schedule

This research was conducted on the construction project of Refinery and Waste Water Treatment Plant owned by PT Golden Union Oil located in Sidoarjo. The selection of this location was based on the fact that the project experienced a significant delay of 9 months, making it a relevant case study for analysis. The project involved various parties, including the owner, contractors, and engineering consultants, which provided an opportunity to explore the causes of the delay from different points of view.

The research time lasted for six months, starting from the preparation stage to the completion of the analysis. The preparation phase included a literature review and questionnaire development. The data collection stage was conducted over two months, involving surveys to respondents and in-depth interviews. The final stage involved analyzing the data, developing recommendations, and simulating the implementation of the solution. This structured research timeframe was designed to ensure that all stages were conducted comprehensively, so that the results obtained could provide applicable and relevant recommendations.

Research Design and Approach Technique

This research uses a quantitative approach with a case study design. The quantitative approach is used to objectively measure the level of influence of variables causing delays through a Likert scale-based questionnaire. This approach allows researchers to obtain numerical data that can be analyzed statistically, providing accurate and measurable results.

In addition, this research adopts a case study design to explore the phenomenon of project delays specifically at PT Golden Union Oil. This case study includes an in-depth analysis of the processes, variables, and interactions between factors causing delays. The combination of quantitative and case study approaches enables this research to generate comprehensive insights and targeted solutions. By combining these two approaches, the research not only explains the phenomenon of delay quantitatively, but also provides a broader context and understanding of the factors that influence it, as well as solutions that can be practically implemented.

RESULTS AND DISCUSSION

Results

Factors Causing Delay

This study identifies the dominant factors causing delays in the construction of the Refinery and Waste Water Treatment Plant project in Sidoarjo. Based on questionnaire analysis and in-depth interviews, the main factors include lack of careful planning, poor coordination between relevant parties, delays in material supply, and low quality of labor. In addition, the analysis showed that external environmental factors such as bad weather also contributed to project delays.

In addition to internal factors, financial aspects such as delays in payments from the project owner to the contractor also affected project implementation. In some cases, changes in the scope of work and delays in approving technical documents exacerbated the delay conditions. These findings are consistent with the results of previous studies using similar methods.

Influence of Factors on Delay

Based on a Likert scale, the degree of influence of each variable was measured to determine the priority of handling. The factor "lack of work planning" had the highest significant score, indicating that planning is a key element in reducing delays. The variable "poor coordination" came in second, followed by "delay in material supply."

The data obtained was then further analyzed using Current State Mapping, which showed the processes that were hampered by these variables. The Current State Mapping Network Diagram shows that the workflow tends to be disrupted at the material procurement stage, especially for items that require import time.

Tardiness Reduction Techniques

In the Improve phase, the Lean Construction approach is applied to minimize time wastage. Value Stream Mapping technique was used to identify value-added and non-value-added activities. Based on this analysis, measures such as the development of a realistic schedule and improved communication between project parties were designed to overcome the main bottlenecks.

Other solutions included the implementation of Daily Huddle Meeting to improve daily coordination, as well as Last Planner System that ensured all activities had clear planning and on-target realization. This strategy successfully reduced the project cycle time by 57.49% compared to the initial condition.

Lean Construction Implementation Results

The implementation of Lean Construction solutions resulted in significant changes in project management. Future State Mapping measurements showed an increase in efficiency of 57.49%, in line with the set target. Just-In-Time techniques were applied to ensure timely availability of materials, while the implementation of Kanban helped control production flow. This success shows the great potential of Lean Construction in the management of construction projects in Indonesia.

Table 1. Value Stream Mapping

No.	Respondent Activity	Reference	Category
1	Know how to make a *value stream* map	Han, 2008	*Planning*
2	Perform *value stream* mapping based on the workflow of each job.	Picchidan Granja, 2005	*Planning*
3	Observe the cycle time based on the processing time, inspection	Zawislak, 2005	*Controlling*

	time, waiting time, and transfer time of each job.		
4	Categorize activities that valuable activities, non-valuable activities and non-valuable activities but it takes	M Watson, 2003	*Controlling*
5	Revised the *value stream* mapping, proposed improvements required	Zawislak, 2005	*Evaluation*
6	Create clear work standards by defining sequences, rhythm and supply	O Salem, 2005	*Work Instruction*

Table 2. *Just in Time*

No.	Respondent Activity	Reference	Category
1	Do not store materials for too long	Tommelein, 1999	*Tools & Materials*
2	Existence of production order kanban and picking kanban for each job	Kim, 2007	*Work Instruction*
3	Complete work in accordance with predetermined targets (quantity and time)	Ohmo, 1995	*Work Instruction*
4	Ensure availability of materials when needed	Tommelein, 1999	*Tools & Materials*
5	There is more attention from the supplier to the development of project implementation	Tommelein, 1999	*Organization & Communication*
6	Complete work according to specifications, no defects	Krisnawati, 2001	*Work Instruction*
7	Control each job to ensure it is in accordance with specifications and completed on time.	Kim, 2007	*Controlling*

Discussion

The Lean Construction approach applied in this study focuses on reducing waste and improving efficiency through the identification of value-added activities. Results show that a reduction in project cycle time of up to 57.49% can be achieved with the right strategy. The findings support previous literature showing the effectiveness of the Lean Construction approach in mitigating project delays.

The Value Stream Mapping method and Last Planner System proved effective in improving workflow. The combination of improved daily communication through Daily Huddle Meetings and the creation of realistic schedules helped reduce coordination bottlenecks. In addition, the Just-In-Time method ensures that the required materials are always available on time, reducing unproductive waiting time.

However, the implementation of Lean Construction also faces challenges. One of them is resistance from those who are used to traditional working methods. This requires training and education to ensure that all parties understand the long-term benefits of this change. In addition, delays in the supply of imported materials remain a challenge, especially in an unstable global context. Possible solutions include diversifying material sources and developing strategic relationships with local suppliers.

In the context of the PT Golden Union Oil project, the application of Lean Construction provided tangible benefits, including improved time and cost efficiency. These results suggest that the approach can be adapted for other construction projects in Indonesia, particularly those facing similar issues. Going forward, further research is needed to explore the integration of Lean Construction with digital technologies such as BIM (Building Information Modeling). These technologies can improve data transparency and accuracy, supporting more effective implementation of Lean strategies.

CONCLUSION

Based on the research conducted, the implementation of Lean Construction as part of the "Improve" phase in the Lean Six Sigma framework proved effective in reducing construction project delays. Using techniques such as Value Stream Mapping and Last Planner System, the research successfully identified the dominant factors causing delays, including lack of proper planning, poor coordination, and delays in material supply. The Lean Construction approach also enabled the elimination of non-value-added activities and optimization of work processes, leading to overall project efficiency.

The implementation results showed a reduction in project cycle time by 57.49%, in line with the set target. These findings support the effectiveness of Lean Construction methods in improving efficiency through the reduction of waste and increased transparency and accuracy in workflow. The implementation of Daily Huddle Meeting and Just-In-Time methods further accelerated decision-making and ensured timely availability of materials, thereby reducing constraints that could potentially delay the project schedule. Overall, the implementation of Lean Construction not only improved the project's time and cost performance but also contributed to better organizational learning, opening up opportunities for the adoption of similar approaches in various other construction projects in Indonesia.

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