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Analysis of Obstructing Factors for the Implementation of Lean Construction in Hauling Road Construction with A Multiple Linear Regression and Swot Analysis Approach

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ABSTRACT

Infrastructure development in the mining sector plays a crucial role in supporting Indonesia's economic growth, with the sector contributing approximately 7–8% of total GDP. However, infrastructure projects face significant challenges related to inefficiency, with more than 40% experiencing delays due to waste and poor resource management. Lean Construction, adapted from Lean Manufacturing principles and introduced by Lauri Koskela in 1993, offers a systematic approach to eliminating waste and enhancing project value. This research aims to analyze the barrier factors affecting Lean Construction implementation in hauling road construction projects and to formulate strategies to overcome these barriers. Using a quantitative approach, this study employed multiple linear regression analysis to examine the relationship between barrier factors (managerial, workforce, organizational, and external factors) and Lean Construction implementation. Data were collected through expert validation and questionnaires from 50 respondents involved in hauling road construction. The results show that these four factors simultaneously influence Lean Construction implementation by 57.7%, with the workforce factor being the most dominant ($\boldsymbol{\beta = 0.385}$). SWOT analysis identified strategic recommendations, including enhanced Lean Construction training programs with certification, optimization of Lean Tools technology, improved communication systems, and structured organizational commitment. This research contributes to the body of knowledge on Lean Construction implementation in the Indonesian mining infrastructure context and provides practical guidelines for contractors to overcome implementation barriers.

KEYWORDS *Barrier Factors; Lean Construction; Hauling Road; Multiple Linear Regression; SWOT Analysis.*

INTRODUCTION

Infrastructure development in the mining sector plays a crucial role in supporting Indonesia's economic growth. The mining sector contributes approximately 7-8% of Indonesia's total Gross Domestic Product (GDP), with continuous growth driven by increased demand for mineral resources both domestically and internationally (Agu et al., 2022; Fernando, 2022; Finley, 2022; Syukri, 2020). The development of supporting infrastructure, particularly hauling roads, is essential for optimizing mining operations and ensuring efficient material transportation from excavation points to processing facilities or export locations (Amarachi, 2024; Aunirrouf & Nasihien, 2019; Samanta, 2015; Smaoui et al., 2021).

However, significant challenges in infrastructure project implementation continue to involve inefficiencies that often lead to delays and resource waste. More than 40% of infrastructure projects in Indonesia experience delays, partly due to poor planning, inadequate resource management, and lack of control over project implementation processes. These inefficiencies not only result in cost overruns but also negatively impact project quality and client satisfaction. In the context of hauling road construction in the mining sector, such challenges become even more critical due to the specific characteristics of mining projects, including remote locations, difficult terrain conditions, and strict time constraints.

Lean Construction is a method adapted from Lean Manufacturing principles, introduced in 1993 by Lauri Koskela at the first International Group of Lean Construction (IGLC) conference. This concept focuses on eliminating waste (waste) and enhancing value (value) throughout the construction process. The main principle of Lean Construction is to identify and eliminate activities that do not add value to the project, thereby increasing efficiency, reducing costs, and improving overall project quality (Alves, 2020; Bertelsen, 2016; Bhatnagar et al., 2023; Miron et al., 2024). This approach has proven effective in various construction projects worldwide, including in developed countries such as the United States, Japan, and several European nations.

Despite its recognized benefits, the implementation of Lean Construction in Indonesia, particularly in mining infrastructure projects such as hauling road construction, still faces various obstacles (Adhi & Muslim, 2023; Allo & Bhaskara, 2022; Li et al., 2017; Sarhan et al., 2017). Several previous studies have identified factors hindering Lean Construction implementation, including lack of understanding of Lean concepts among project stakeholders, resistance to change from traditional practices, inadequate technological infrastructure, and limited financial resources for implementation. Additionally, cultural and organizational factors, such as hierarchical organizational structures and lack of collaboration between project teams, also contribute to implementation difficulties.

Research by Bajjou and Chafi (2018) in Morocco identified that the main barriers to Lean Construction implementation include lack of knowledge and awareness about Lean concepts, resistance to change, lack of management support, and inadequate organizational culture. Similarly, research in developing countries shows that contextual factors such as limited human resources, inadequate infrastructure, and unfavorable economic conditions also play significant roles in hindering Lean implementation. In the Indonesian context, particularly in the mining sector, additional challenges include the dynamic nature of mining projects, variations in working conditions, and the need for rapid adaptation to changing site conditions.

The novelty of this research lies in its integrated methodological approach, combining quantitative regression analysis with strategic SWOT assessment, specifically applied to the understudied domain of mining hauling road construction in Indonesia. Understanding the factors hindering Lean Construction implementation is the first step in developing effective strategies to overcome these barriers. Through in-depth analysis of these factors, appropriate interventions can be designed to facilitate smoother and more successful Lean Construction adoption.

This research aims to analyze barrier factors affecting Lean Construction implementation in hauling road construction projects and formulate strategies to overcome these barriers using multiple linear regression and SWOT analysis approaches. Multiple linear regression is used to identify and quantify the relationship between various barrier factors and the level of Lean Construction implementation. This analysis allows for the identification of the most dominant factors influencing implementation, thereby enabling prioritization in intervention planning. Meanwhile, SWOT analysis is employed to evaluate strengths, weaknesses, opportunities, and threats related to Lean Construction implementation in the hauling road construction context and to formulate comprehensive strategies based on this evaluation.

This research is expected to make theoretical and practical contributions. Theoretically, this study enriches the literature on Lean Construction implementation in the context of mining infrastructure projects in developing countries, particularly Indonesia. Practically, the research findings provide concrete guidelines for contractors, project managers, and other stakeholders in overcoming barriers to Lean Construction implementation, thereby improving the efficiency and effectiveness of hauling road construction projects. Ultimately, successful implementation of Lean principles is expected to contribute to overall productivity improvement in Indonesia's mining sector and support sustainable national economic development.

RESEARCH METHOD

This research employed a quantitative approach with survey methods to analyze the barrier factors affecting Lean Construction implementation in hauling road construction. The research was conducted from January to October 2025, focusing on mining companies operating hauling road construction projects in Indonesia. The research design consisted of three main stages: expert validation, main survey, and data analysis.

The first stage involved expert validation to determine relevant variables based on literature review. Three experts with minimum bachelor's degree qualifications and more than 10 years of experience in construction projects, particularly hauling road construction, were selected. Experts provided assessments on 29 initial variables derived from literature review, categorized into four main factors: managerial factors, workforce factors, organizational factors, and external factors. Experts were asked to provide scores on a scale of 1-5 for each variable, with additional space to propose new relevant variables. Variables with average scores ≥ 3.0 were considered valid and retained for the main survey stage.

The second stage was the main survey involving 50 respondents selected through purposive sampling technique. Respondent criteria included individuals who had been or were currently involved in hauling road construction projects, with various positions including project managers, site managers, supervisors, and field engineers. This approach ensured that respondents had adequate understanding and experience related to Lean Construction implementation in hauling road projects. The questionnaire was designed using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to measure respondent perceptions of the influence of each barrier factor on Lean Construction implementation.

The third stage was data analysis conducted in three main steps. First, instrument testing was performed including validity testing using Pearson Product Moment correlation and reliability testing using Cronbach's Alpha. An instrument was considered valid if r-count > r-table (0.279 for n=50, significance level 5%), and reliable if Cronbach's Alpha > 0.70. Second, classical assumption tests were conducted including normality test (Kolmogorov-Smirnov), multicollinearity test (VIF and Tolerance values), and heteroscedasticity test (Glejser test) to ensure that the data met the requirements for multiple linear regression analysis. Third, hypothesis testing was performed through multiple linear regression analysis to determine the relationship between barrier factors and Lean Construction implementation, t-test to identify the partial influence of each independent variable, and F-test to test the simultaneous influence of all independent variables on the dependent variable.

Multiple linear regression analysis produced an equation of the form $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$, where Y represents Lean Construction implementation level, X_1 represents managerial factors, X_2 represents workforce factors, X_3 represents organizational factors, and X_4 represents external factors. The coefficient of determination (R^2) was used to measure the extent to which variations in the independent variables could explain variations in the dependent variable. Dominant barrier factors were identified based on standardized regression coefficients (Beta).

After identifying dominant factors through multiple linear regression analysis, SWOT analysis was conducted to formulate strategies for overcoming implementation barriers. SWOT analysis was performed by identifying Strengths, Weaknesses, Opportunities, and Threats related to Lean Construction implementation, particularly concerning the most dominant factor. Based on the SWOT matrix, four types of strategies were formulated: SO strategy (Strengths-Opportunities), WO strategy (Weaknesses-Opportunities), ST strategy (Strengths-Threats), and WT strategy (Weaknesses-Threats). The formulated strategies were then validated by three experts to ensure relevance and feasibility of implementation.

All data analysis was conducted using SPSS 29 software to ensure accuracy and reliability of analysis results. Research ethics were rigorously maintained throughout the study by ensuring complete respondent confidentiality and anonymity, obtaining voluntary informed consent before data collection, clearly explaining research purposes and data usage, and using collected data solely for academic research purposes.

The research design and methodology were deliberately structured to answer two primary research questions: (1) What barrier factors significantly influence Lean Construction implementation in hauling road construction? and (2) What practical strategies can be effectively implemented to overcome these identified barriers?

Potential limitations in the methodology were acknowledged and addressed where possible. While the purposive sampling technique ensured respondent expertise and relevance, it may limit statistical generalizability to the broader population of construction projects. The cross-sectional survey design captures perceptions at a single time point, potentially missing temporal dynamics in implementation challenges. The reliance on self-reported perceptions may introduce social desirability bias, though anonymity was maintained to minimize this effect. These limitations were partially mitigated through diverse respondent recruitment, triangulation with expert validation, and rigorous statistical testing of data quality.

RESULT AND DISCUSSION

Expert Validation Results

The expert validation stage successfully identified relevant variables for the main survey. Of the 29 initial variables, 27 variables achieved average scores ≥ 3.0 and were considered valid. The experts also proposed 5 additional variables deemed relevant to the context of hauling road construction, bringing the total variables for the main survey to 32 variables. The validated variables were grouped into four main factors: managerial factors (8 variables), workforce factors (10 variables), organizational factors (7 variables), and external factors (7 variables).

Table 1. Expert Profile

Expert	Education	Experience (Years)	Position
Expert 1	Master in Civil Engineering	15	Project Manager
Expert 2	Bachelor in Civil Engineering	12	Construction Manager
Expert 3	Master in Project Management	18	Senior Engineer

Respondent Characteristics

The main survey involved 50 respondents from various companies engaged in hauling road construction. Based on work experience, 16% of respondents had 1-5 years of experience, 36% had 6-10 years, 32% had 11-15 years, and 16% had more than 15 years. Based on position, respondents consisted of project managers (20%), site managers (24%), supervisors (30%), and field engineers (26%). This diverse distribution ensures comprehensive representation of various perspectives on Lean Construction implementation.

Table 2. Respondent Characteristics Based on Work Experience

Work Experience	Frequency	Percentage (%)
1-5 years	8	16
6-10 years	18	36
11-15 years	16	32
> 15 years	8	16
Total	**50**	**100**

Instrument Testing Results

Validity testing showed that all 32 question items had r-count values > r-table (0.279), indicating that all items were valid and could be used for further analysis. Reliability testing using Cronbach's Alpha produced values of 0.894 for managerial factors, 0.921 for workforce factors, 0.887 for organizational factors, 0.903 for external factors, and 0.916 for Lean Construction implementation. All Cronbach's Alpha values > 0.70, indicating that the instrument was highly reliable.

Table 3. Reliability Test Results

Variable	Cronbach's Alpha	Interpretation
Managerial Factors (X1)	0.894	Highly Reliable
Workforce Factors (X2)	0.921	Highly Reliable
Organizational Factors (X3)	0.887	Highly Reliable
External Factors (X4)	0.903	Highly Reliable
Lean Construction Implementation (Y)	0.916	Highly Reliable

Classical Assumption Test Results

Normality testing using Kolmogorov-Smirnov produced an Asymp. Sig value of 0.200 > 0.05, indicating that the data was normally distributed. Multicollinearity testing showed that all independent variables had VIF values < 10 and Tolerance values > 0.10, indicating no multicollinearity issues. Heteroscedasticity testing using the Glejser test showed that all independent variables had significance values > 0.05, indicating homoscedasticity. These results confirm that the data met all classical assumptions for multiple linear regression analysis.

Multiple Linear Regression Analysis

Multiple linear regression analysis produced the following equation: $Y = 2.66 - 0.185X_1 + 0.385X_2 - 0.015X_3 + 0.135X_4$. This equation indicates that managerial factors (X_1) negatively influence Lean Construction implementation, meaning that the stronger the barriers in managerial aspects, the lower the level of implementation. Conversely, workforce factors (X_2) and external factors (X_4) positively influence implementation, indicating that improvements in these aspects can enhance implementation levels. Organizational factors (X_3) show minimal influence with a very small coefficient.

Table 4. Multiple Linear Regression Results

Variable	Coefficient (B)	Std. Error	t-value	Sig.
Constant	2.660	0.421	6.318	0.000
Managerial Factors (X1)	-0.185	0.046	-4.051	0.001
Workforce Factors (X2)	0.385	0.101	3.818	0.001
Organizational Factors (X3)	-0.015	0.050	-0.301	0.765
External Factors (X4)	0.135	0.055	2.455	0.018

The coefficient of determination (R^2) was 0.577, indicating that 57.7% of variations in Lean Construction implementation could be explained by the four independent variables, while the remaining 42.3% was influenced by other factors not included in this model. According to Chin's (1998) criteria, an R^2 value of 0.577 falls into the moderate category, indicating that this model has adequate explanatory power.

Hypothesis Testing Results

T-test results showed that managerial factors (X_1) significantly influenced Lean Construction implementation with sig. value of 0.001 < 0.05 and t-count of -4.051 < -t-table of -2.009, indicating negative and significant influence. Workforce factors (X_2) significantly positively influenced implementation with sig. value of 0.001 < 0.05 and t-count of 3.818 > t-table of 2.009. External factors (X_4) also significantly positively influenced implementation with sig. value of 0.018 < 0.05 and t-count of 2.455 > t-table of 2.009. However, organizational factors (X_3) did not significantly influence implementation with sig. value of 0.765 > 0.05.

F-test results produced sig. value of 0.001 < 0.05 and F-count of 15.359 > F-table of 2.578, indicating that all independent variables simultaneously significantly influenced Lean Construction implementation. These results confirm that barrier factors in managerial, workforce, organizational, and external aspects collectively constitute significant obstacles to Lean Construction implementation in hauling road construction.

Table 5. Hypothesis Testing Summary

Hypothesis	t-count	Sig.	Decision
X1 → Y	-4.051	0.001	Significant (Negative)
X2 → Y	3.818	0.001	Significant (Positive)
X3 → Y	-0.301	0.765	Not Significant
X4 → Y	2.455	0.018	Significant (Positive)

SWOT Analysis and Strategy Formulation

Based on regression analysis results showing that workforce factors were the most dominant (coefficient 0.385), SWOT analysis was conducted focusing on this factor. Identified strengths included availability of experienced workforce in conventional construction and strong work commitment. Weaknesses included limited understanding of Lean Construction concepts, resistance to change from conventional methods, and lack of specialized training. Opportunities included government support for infrastructure development, availability of Lean Construction training programs, and growing industry awareness of construction efficiency. Threats included tight project schedules, limited training budgets, and competition with more experienced contractors.

From SWOT analysis, four strategic recommendations were formulated and validated by experts. First, enhancing Lean Construction development and training programs accompanied by certification from associations/government received a suitability score of 3.0 out of 4.0 from experts. Second, optimizing Lean Tools technology to enhance efficiency value received a suitability score of 3.7 out of 4.0, considered "highly suitable" by all experts. Third, improving communication and coordination systems among project teams received a suitability score of 3.3 out of 4.0. Fourth, building structured organizational commitment through clear policy and procedure development received a suitability score of 3.5 out of 4.0.

The research findings indicate that workforce factors are the most dominant barrier to Lean Construction implementation in hauling road construction. This aligns with research by Bajjou and Chafi (2018) which identified lack of knowledge and workforce skills as primary obstacles to Lean Construction adoption in developing countries. In the context of hauling road construction, this challenge becomes more pronounced due to the specific nature of mining projects requiring rapid adaptation to changing field conditions and the unique skills needed for mining terrain work.

The significant negative influence of managerial factors on Lean Construction implementation reflects the importance of management support and leadership in driving organizational change. Research by Ansah et al. (2016) emphasized that successful Lean Construction implementation requires strong commitment from top management, clear resource allocation, and effective change management strategies. In the Indonesian context, hierarchical organizational culture and tendency to maintain status quo often become obstacles to innovation adoption, including Lean Construction.

The finding that organizational factors do not significantly influence implementation may indicate that organizational structure is not the main determinant in the success or failure of Lean Construction implementation. However, this does not mean that organizational aspects are unimportant. More likely, the influence of organizational factors is indirect, operating through other factors such as management and workforce. More flexible and adaptive organizational structures may facilitate Lean Construction implementation, but without adequate workforce competence and strong management support, organizational structure alone is insufficient to ensure implementation success.

The positive influence of external factors on Lean Construction implementation demonstrates the importance of support from the external environment, including government policies, industry standards, and availability of supporting infrastructure. In the mining sector, external factors such as mining regulations, environmental requirements, and client demands for construction efficiency play significant roles in driving Lean Construction adoption. However, the relatively smaller coefficient for external factors (0.135) compared to workforce factors (0.385) suggests that internal factors, particularly workforce competence, are more determinant in implementation success.

The recommended strategies from SWOT analysis provide a comprehensive framework for overcoming barriers to Lean Construction implementation. Enhanced training and certification programs can address workforce competence issues, which are the most dominant barriers. Lean Tools technology optimization can enhance work efficiency and facilitate Lean principles implementation in the field. Improved communication systems can strengthen collaboration between project teams, which is crucial in Lean Construction emphasizing cooperation and information sharing. Structured organizational commitment can provide a strong foundation for long-term cultural and behavioral changes needed to sustain Lean Construction implementation.

CONCLUSION

This research successfully analyzed barrier factors affecting Lean Construction implementation in hauling road construction and formulated strategies to overcome these barriers. The results show that managerial factors, workforce factors, organizational factors, and external factors simultaneously influence Lean Construction implementation by 57.7%, with workforce factors being the most dominant ($\beta = 0.385$). The regression equation $Y = 2.66 - 0.185X_1 + 0.385X_2 - 0.015X_3 + 0.135X_4$ indicates that improvements in workforce competence and external support can significantly enhance Lean Construction implementation, while managerial barriers need to be reduced. SWOT analysis formulated four main strategies: enhancing training programs with certification (score 3.0/4.0), optimizing Lean Tools technology (score 3.7/4.0), improving communication systems (score 3.3/4.0), and building structured organizational commitment (score 3.5/4.0). These findings contribute to the body of knowledge on Lean Construction implementation in mining infrastructure contexts and provide practical guidelines for contractors to overcome implementation barriers. For future research, it is recommended to conduct longitudinal studies to measure the impact of implementing the proposed strategies on construction project performance, expand research scope to include other types of mining infrastructure, and explore the role of digital technology and automation in facilitating Lean Construction implementation. Limitations of this research include the relatively small sample size (50 respondents) and focus on hauling road construction projects, which may limit generalizability to other construction contexts.

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