Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 8, No.1, January 2026, pp. 02601016-01 ~ 02601016-016
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v8i1.2394

Optimising Time Efficiency in Green Retrofit Jetty Projects through Envision and Lean-Based Value Stream Mapping

Aprilian Ismana[1*], Mawardi Amin[1], Pio Ranap Tua Naibaho[2], Deprizon Syamsunur[3]

[1]Department of Civil Engineering, Mercu Buana University, Jl. Meruya Selatan No. 1, Kembangan, Jakarta Barat, 11650, Indonesia

[2]Department of Civil Engineering, Tama Jagakarsa University, Jl. TB Simatupang No.152, Jakarta Selatan, DKI Jakarta 12530, Indonesia

[3]Department of Civil Engineering, Faculty of Engineering, Technology and Built Environment, UCSI University, UCSI Heights, 1, Jln UCSI, Taman Connaught, 56000 Wilayah Persekutuan, Wilayah Persekutuan Kuala Lumpur, Malaysia

*aprilian87@gmail.com

Abstract. Indonesia, as a strategic global maritime axis, has only 7.03% of its islands equipped with jetties, and jetty construction poses environmental challenges due to emissions and ecological impacts. Green retrofitting provides a sustainable solution by improving energy efficiency in existing jetties. The Envision rating system guides the transition from conventional to green infrastructure, assessing quality of life, leadership, resource allocation, natural environment, and climate resilience. Despite its benefits, 32% of green projects experience delays. This study analyzes the key factors influencing time performance optimization in Green Retrofit Jetty projects using Lean–Value Stream Mapping (VSM). Using SEM-PLS, ten critical factors were identified. Lean–VSM facilitates process visualization and waste elimination. The Green Retrofit Jetty, achieving an Envision Platinum rating, reduced project duration from 250 to 220 days, demonstrating a 12% improvement in time performance while supporting efficient and sustainable jetty development.

Keywords: Envision, green retrofit, jetty, time optimisation, lean construction, SEM-PLS, value stream mapping

(Received 2025-07-19, Revised 2025-11-03, Accepted 2025-12-22, Available Online by 2026-01-13)

1. Introduction

The rapid rise of carbon dioxide (CO_2) emissions has become one of the most pressing environmental challenges in the 21st century. Data from *Our World in Data* indicates that global CO_2 emissions have surged from 6 billion tonnes in the 1950s to 35 billion tonnes in 2022. This significant increase contributes to global warming, leading to more frequent and severe natural disasters such as floods, droughts and storms [1]. Nations with high industrial growth and dependence on fossil fuels are the main contributors. In response, Indonesia has pledged to reduce its greenhouse gas emissions by 31.89 percent through national efforts by 2030 (NDC Indonesia, 2022).

Given these circumstances, green infrastructure has emerged as a key strategy to promote sustainability and environmental resilience. The Environmental Performance Index (EPI) and the Sustainable Development Goals (SDGs) highlight the importance of adopting environmentally responsible practices. With Indonesia currently ranked 162nd globally in the 2024 EPI report, efforts to enhance environmental governance are essential. Green initiatives such as the Greenship certification programme promote efficient use of water, energy and materials [2,3].

Green infrastructure is particularly relevant for coastal and maritime development, including jetty and port projects. Integrating sustainable construction practices such as the use of environmentally friendly materials and energy-saving designs helps reduce environmental impact while supporting economic growth [4,5]. However, such projects are often hindered by delays arising from financial limitations, lack of coordination among stakeholders and technical difficulties. The scarcity of certified professionals and the complexity of compliance with green standards further contribute to these challenges [6,7].

Construction delays are a multidimensional problem in green projects. A comparative study found that 32.3 percent of green projects experience delays, compared to 15.9 percent of conventional projects. Moreover, green retrofitting projects tend to take 6 to 9 percent longer than planned [8,9]. These delays are exacerbated by poor communication, inadequate planning, and untimely delivery of materials [10,11]. Internal issues such as lack of experience among contractors and suboptimal scheduling also play a role [12].

To overcome these inefficiencies, lean construction offers a promising solution. It focuses on eliminating waste, streamlining processes and improving workflow efficiency. Among various tools, Value Stream Mapping (VSM) is especially effective in identifying non-value-adding activities and increasing process transparency [13,14]. VSM application in construction has proven to boost productivity and reduce lead times while supporting sustainable project delivery. VSM has proven effective in identifying waste and optimizing processes in maritime-based industries. Meanwhile, Fitriadi and Ayob (2024) [15] demonstrated that integrating VSM with sustainability indicators can reduce non-value-added activities while improving environmental, social, and economic performance in traditional shipyard industries. This approach is highly relevant for jetty infrastructure sectors facing similar challenges in efficiency and sustainability. According to Espinoza (2021), lean VSM has the potential to improve time efficiency by up to 17 per cent in construction projects [16]. Although various studies have discussed the application of the Envision Framework or the Lean Construction approach separately, research that integrates both approaches within the context of jetty retrofitting remains limited. Most previous studies have focused on assessing the sustainability of new projects rather than optimizing existing projects using the Value Stream Mapping method.

Although green infrastructure and lean construction have each demonstrated potential, their integration in the context of jetty development remains underexplored. Previous studies typically address environmental sustainability or project efficiency in isolation. [17] investigated the time and cost effectiveness of formwork systems, while [18] explored the use of steel lathe waste in concrete for enhanced sustainability. Lean manufacturing concepts have been discussed in the context of the bolt industry [19], while Life Cycle Assessment has been used to assess environmental impacts in the furniture industry [20]. Meanwhile, [21] examined soft soil consolidation, a factor relevant to jetty construction. Yet, none of these studies offer an integrated framework combining green retrofitting and lean methods for maritime infrastructure.

This research aims to fill that gap by integrating Green Retrofit Jetty principles with Lean Construction tools, specifically using Value Stream Mapping. The study is positioned at the intersection of five key domains: green concepts, jetty infrastructure, lean methodology, time performance and data analysis. The objective is to explore and evaluate how the integration of these approaches can improve time performance in jetty development projects in Indonesia. The findings are expected to contribute to more sustainable, efficient and adaptive practices for coastal infrastructure.

2. Methods

This study employs a quantitative research design to evaluate the impact of integrating Green Retrofit Jetty (GRJ) principles and Lean Construction using Value Stream Mapping (VSM) on the time performance of maritime infrastructure projects. The research follows a sequential methodology aligned with three core research questions: identifying the most influential factors (RQ-1), implementing Envision guidelines (RQ-2), and analysing Lean-VSM application in optimising project time performance (RQ-3).

The initial phase of the study involved defining the research questions and designing a structured questionnaire. This instrument was developed from a synthesis of recent literature and expert consultations and validated by three professionals with expertise in green construction and project scheduling. A pilot survey was conducted with five individuals to assess the clarity and interpretability of the questions. Necessary revisions were made before distributing the final version to a wider sample.

The research involved a survey of 100 respondents selected through purposive sampling. These respondents included directors, general managers, engineers, and key stakeholders involved in jetty construction projects, each with at least five years of experience. Data were collected through multiple techniques, including questionnaires, semi-structured interviews, and direct field observations. Supplementary secondary data were drawn from official project documents such as retrofit design drawings, construction schedules, Bills of Quantity, and progress reports [22,23]. The final SEM-PLS analysis used 87 valid responses. This sample meets the “10 times rule”, as the construct with the most indicators had 8 items and the maximum incoming paths to a latent variable were 2, requiring at least 80 respondents. The size is also sufficient to achieve adequate statistical power ($\alpha = 0.05$, power = 0.8), ensuring reliable estimation of measurement and structural models.

The study investigates three main variables. Two are independent: Green Retrofit Jetty (X1) and Lean-Value Stream Mapping (X2), while Time Performance (Y) serves as the dependent variable. These variables were operationalised into measurable indicators based on established research [8,24]. The indicators were further broken down into sub-factors representing various components of time performance in jetty construction projects.

Data were analysed using Structural Equation Modeling with SmartPLS software. SEM was chosen due to its capacity to evaluate complex, multi-variable relationships and assess both measurement and structural models. The model’s validity and reliability were tested using Confirmatory Factor Analysis (CFA), Cronbach’s Alpha, and Composite Reliability. Further statistical tests, including t-tests and F-tests, were performed to examine the relationships between variables, while the Kolmogorov-Smirnov and Durbin-Watson tests were employed to check data normality and autocorrelation [25]. Key SEM-PLS assumptions and criteria were addressed:

- Multicollinearity: assessed via Variance Inflation Factor (VIF < 5).
- Outer Loading: indicators must have loadings ≥ 0.7; 0.4–0.7 considered contextually.
- Average Variance Extracted (AVE): ≥ 0.5 for convergent validity.
- Composite Reliability (CR): ≥ 0.7 for internal consistency.
- Discriminant Validity: checked using HTMT < 0.85.
- Normality and Autocorrelation: assessed via Kolmogorov-Smirnov and Durbin-Watson tests.

All stages of the research were illustrated in a flow diagram to demonstrate the logical progression from problem formulation to empirical testing. The final outcome is expected to provide a replicable framework that integrates GRJ, Lean Construction, and VSM approaches to enhance time efficiency in maritime infrastructure projects.

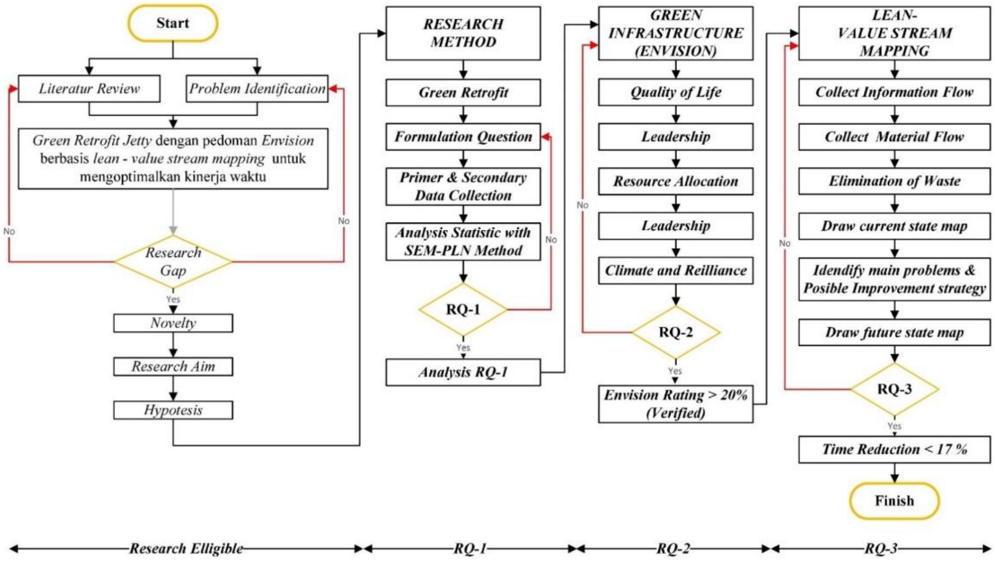


Figure 1. Research Flow Diagram

3. Results and Discussion

The analysis began with data obtained from a validated questionnaire developed based on previous studies. The research instrument included three main dimensions: variables, key factors, and sub-factors, each representing components that potentially influence time performance in sustainable jetty construction projects. A total of 87 valid responses were collected from professionals involved in infrastructure development, including owners, consultants, contractors, engineers, site managers, and supervisors. Respondents were selected according to their educational background, work experience, and roles in related projects to ensure the accuracy and relevance of the data.

The findings indicate that both Green Retrofit and Lean Value Stream Mapping (VSM) significantly affect project time efficiency. Green Retrofit practices that follow Envision standards were found to support the redesign of workflows through environmentally conscious methods. Lean VSM, on the other hand, proved effective in identifying non-value-adding activities and sources of waste that contribute to project delays. These approaches work together by aligning sustainability objectives with improvements in operational efficiency.

The reliability of the indicators and the internal consistency of the constructs were confirmed through statistical results, with most values exceeding the standard thresholds for factor loadings, composite reliability, and average variance extracted. The model also showed strong explanatory power in accounting for variation in time performance.

Among the most influential factors were the use of renewable energy, reduction of operational waste and water consumption, and enhanced project planning. Workflow mapping further revealed areas of inefficiency that could be addressed through lean techniques. These findings support the practical relevance of combining sustainable infrastructure practices with tools for optimising work processes.

3.1. Data Analysis using SEM-PLS

Structural Equation Modeling–Partial Least Squares (SEM-PLS) is a variance-based structural equation modeling technique that allows for complex model estimation, particularly when data distributions are non-normal, sample sizes are small, or the research is focused on prediction rather than theory testing [26]. The initial step in applying SEM-PLS involves importing data from the processed questionnaire in CSV format. Subsequently, the structural path model is constructed to connect latent variables based on the theoretical framework within the inner model. The outer model is then specified to represent the relationships between latent variables and their corresponding observable indicators.

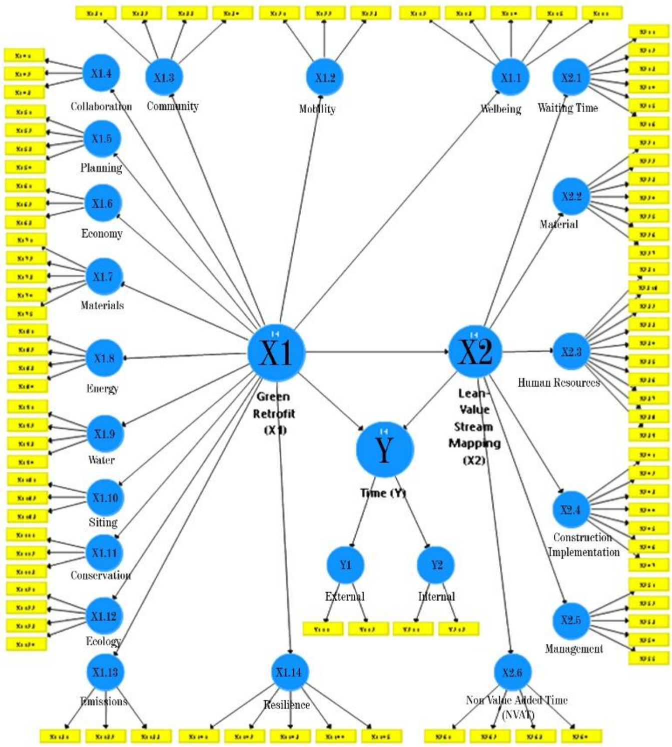


Figure 2. SEM-PLS Path Modeling Diagram

The structural model consists of three primary latent variable constructs. Path analysis was then conducted using the SEM-PLS method based on the main diagram and corresponding tables. This analysis generated 22 distinct paths that aid in understanding the interrelationships among the variables. The full list of these paths is provided in Table 1 below:

Table 1. SEM-PLS Main Modeling Relationship Paths

Variabel Manifest/ Indicator	*Variabel Laten*	*Variabel Intervening/ Median*
X1.1.1 – X1.1.5	*Welbeing (X1.1)*	
X1.2.1 – X1.2.3	*Mobility (X1.2)*	
X1.3.1 – X1.3.4	*Community (X1.3)*	
X1.4.1 – X1.4.3	*Collaboration (X1.4)*	
X1.5.1 – X1.5.4	*Planning (X1.5)*	
X1.6.1 – X1.6.3	*Econom (X1.6)*	
X1.7.1 – X1.7.5	*Materials (X1.7)*	*Green Retrofitting*
X1.8.1 – X1.8.4	*Energy (X1.8)*	***(X1)***
X1.9.1 – X1.9.4	*Water (X1.9)*	
X1.10.1 – X1.10.3	*Siting (X1.10)*	
X1.11.1 – X1.11.3	*Conservation (X1.11)*	
X1.12.1 – X1.12.4	*Ecology (X1.12)*	
X1.13.1 – X1.13.3	*Emissions (X1.13)*	
X1.14.1 – X1.14.5	*Resilience (X1.14)*	
X2.1.1 – X2.1.6	*Waktu Tunggu (X2.1)*	*Lean-Value Stream*
X2.2.1 – X2.2.7	*Material/Bahan (X2.2)*	*Mapping*
X2.3.1 – X2.3.10	*Sumber Daya Manusia (X2.3)*	***(X2)***

X2.4.1 – X2.4.7	*Pelaksanaan Konstruksi (X2.4)*	
X2.5.1 – X2.5.5	*Manajemen (X2.5)*	
X2.6.1 – X2.6.4	*Non Value Added Time (X2.6)*	
Y.1.1 – Y1.1.2	*Eksternal*	*Time **(Y)***
Y.2.1 – Y1.2.2	*Internal*	

Table 2. Main Path Analysis of the Modelling

No	Path Analysis
1	Indicator Variable → Latent Variable
2	Indicator Variable → Latent Variable (Mediated)
3	Mediating Variable Lean-VSM → Latent Variable Time Performance
4	Mediating Variable Green Retrofit → Mediating Variable Lean-VSM
5	Mediating Variable Green Retrofit → Latent Variable Time Performance
6	Latent Variable Green Retrofit → Latent Variable Lean-VSM → Latent Variable Time Performance

3.2. Outer Model Analysis

This study applied a reflective measurement model, evaluated through individual item reliability, construct reliability, average variance extracted, and discriminant validity. The first three assessments represent convergent validity, which measures the strength of correlation between indicators and their constructs. Indicator reliability is confirmed when outer loading values are ≥ 0.7, though values ≥ 0.5 are acceptable and values ≤ 0.4 are excluded. Construct reliability, evaluated through composite reliability and Cronbach's alpha, is considered acceptable if the values exceed 0.70. The evaluation was conducted using SmartPLS, which calculates path coefficients through the PLS algorithm. The resulting values confirm that all indicators meet the minimum threshold, supporting the reliability and convergent validity of the model.

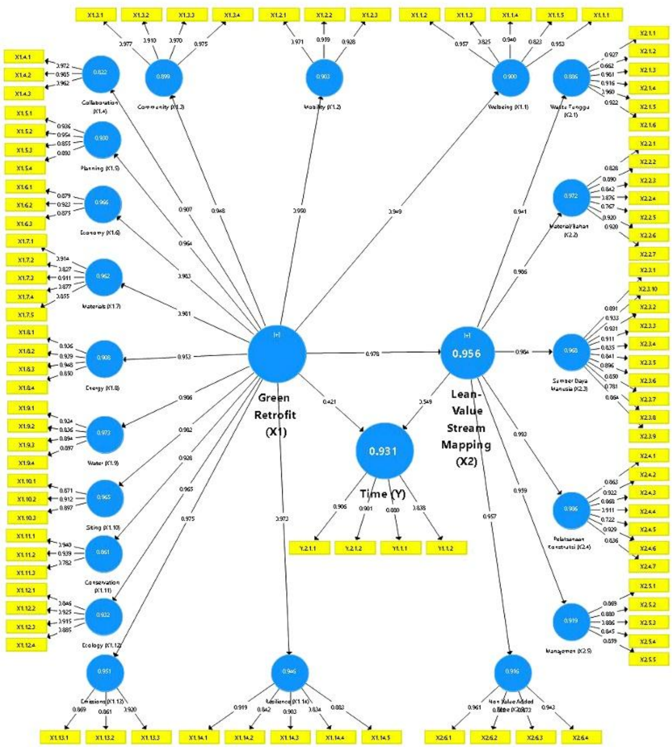


Figure 3. SEM Diagram Results of T-Value and Path Coefficients

Internal consistency reliability is used to determine how well a set of indicators consistently measures their associated latent variable. This is assessed using both composite reliability and Cronbach's alpha.

Composite reliability values between 0.6 and 0.7 are deemed acceptable [27], while Cronbach's alpha values above 0.6 indicate good reliability [28]. As presented in Table 3, all constructs in the model exceeded these thresholds, with values such as 0.994 for Green Retrofit and 0.970 for Community, confirming strong internal consistency. Furthermore, the unidimensionality of constructs was verified, with all composite reliability values exceeding 0.7, indicating that each construct reliably measures a single dimension of the latent variable. For example, the "Construction Phase" construct achieved a composite reliability of 0.883, thus confirming its classification as reliable.

Table 3. Construct Reliability Test Results Based on Convergent Validity

No	Main Factor	Cronbach's Alpha	rho_A	Composite Reliability	(AVE)
1	Collaboration (X1.4)	0,972	0,972	0,982	0,947
2	Community (X1.3)	0,970	0,971	0,978	0,919
3	Conservation (X1.11)	0,865	0,870	0,919	0,792
4	Ecology (X1.12)	0,915	0,916	0,940	0,798
5	Economy (X1.6)	0,872	0,875	0,922	0,797
6	Emissions (X1.13)	0,859	0,864	0,914	0,781
7	Energy (X1.8)	0,938	0,941	0,956	0,845
8	External (Y1)	0,770	0,772	0,897	0,813
9	Green Retrofit (X1)	0,994	0,994	0,994	0,757
10	Internal (Y2)	0,869	0,869	0,939	0,884
11	Lean-Value Stream Mapping (X2)	0,990	0,990	0,990	0,726
12	Management (X2.5)	0,918	0,921	0,939	0,753
13	Materials/Resources (X2.2)	0,943	0,947	0,954	0,748
14	Materials (X1.7)	0,925	0,927	0,944	0,770
15	Mobility (X1.2)	0,949	0,949	0,967	0,908
16	Non-Value Added Time (X2.6)	0,917	0,923	0,942	0,804
17	Construction Execution (X2.4)	0,944	0,948	0,955	0,752
18	Planning (X1.5)	0,930	0,931	0,951	0,829
19	Resilience (X1.14)	0,925	0,926	0,943	0,769
20	Siting (X1.10)	0,874	0,874	0,922	0,799
21	Human Resources (X2.3)	0,966	0,967	0,970	0,765
22	Time (Y)	0,904	0,905	0,933	0,778
23	Waiting Time (X2.1)	0,950	0,953	0,962	0,812
24	Water (X1.9)	0,911	0,912	0,937	0,789
25	Well-being (X1.1)	0,941	0,945	0,956	0,813

3.3. Unidimensionality Analysis

Unidimensionality analysis is conducted to validate the accuracy of measurement by ensuring that each construct reflects a single underlying dimension. This evaluation uses both Cronbach's alpha and composite reliability, with a threshold of 0.7 for each. Composite reliability is the "trustworthiness value" of a construct based on how its indicators relate to each other. As shown in the table, all constructs meet the unidimensionality criteria, with composite reliability values exceeding 0.7. For instance, the latent construct representing Green Retrofit (X1.1) demonstrates a composite reliability score of 0.994, far above the minimum requirement, indicating strong construct validity. The results are visually illustrated in Figure 3, which presents the composite reliability values generated through SmartPLS.

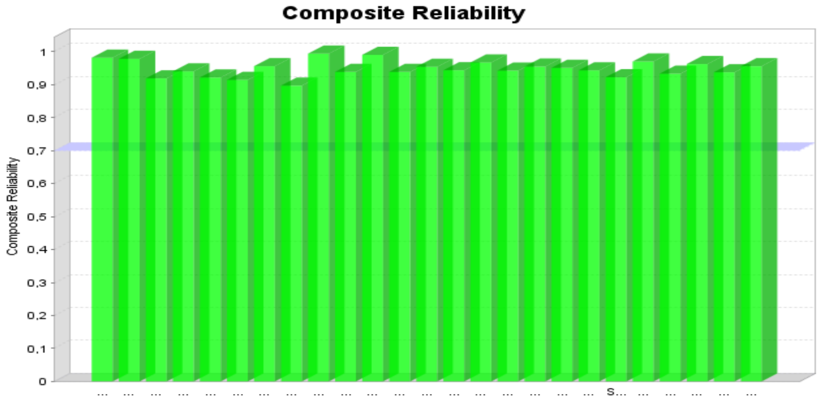


Figure 4. Composite Reliability Value Diagram

3.4. Convergent Validity

Convergent validity assesses the extent to which multiple indicators of the same construct are in agreement, indicating that they measure the same underlying concept [28]. This is typically evaluated using the Average Variance Extracted (AVE), where a minimum value of 0.5 is required to confirm that the construct explains at least 50 percent of the variance of its indicators [29]. AVE is a statistical measure used to assess convergent validity in measurement models. AVE measures the proportion of variance in indicators that can be explained by their latent construct, reflecting the extent to which the indicators truly represent the intended construct. A higher AVE value indicates that the indicators have a stronger relationship with the latent construct and contain less measurement error. Based on the results, all constructs in the model achieved AVE values greater than 0.5, satisfying the convergent validity criteria. For instance, the "Technical Design" construct recorded an AVE of 0.760, indicating that it has strong convergent validity and that its indicators reliably represent the intended latent variable.

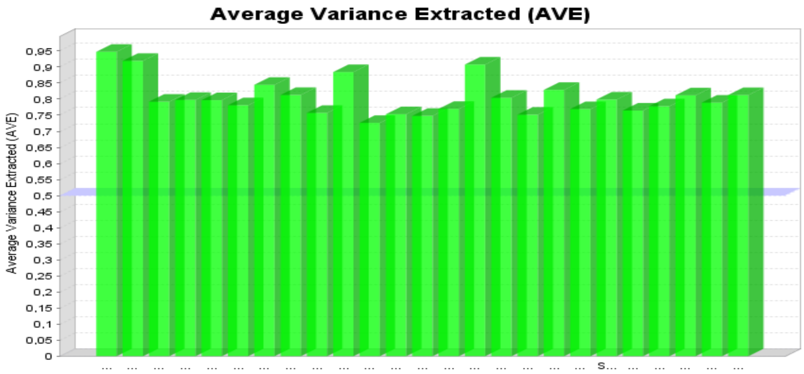


Figure 5. Average Variance Extracted (AVE) Value Diagram

3.5. Discriminant Validity

Discriminant validity refers to the degree to which constructs are distinct from one another and not highly correlated with different constructs in the model [28]. This validity is assessed using several criteria in SmartPLS, including cross loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait (HTMT) rasio [30]. A strong discriminant validity indicates that each construct captures a unique aspect of the model, supporting the accuracy and clarity of the structural framework.

3.6. Inner Model Analysis (Path Coefficients)

Inner loading analysis involves measuring the path coefficients between constructs to evaluate the significance and strength of their relationships, as well as to test the proposed hypotheses. Path coefficient values range from –1 to +1, with values closer to +1 indicating a stronger positive relationship between two constructs. Conversely, values approaching –1 suggest a negative relationship. In this context, a higher path coefficient implies a more significant and robust connection between the constructs under examination [31].

3.7. SEM-PLS Path Coefficients and T-Statistic Analysis

The next step in the SEM-PLS analysis involves hypothesis testing by examining the T-statistic values of the path coefficients. These values are generated through the bootstrapping procedure in SmartPLS, using the Calculate PLS Bootstrapping function. The T-statistic is employed to assess the statistical significance of the relationships between latent constructs. With a sample size of 82 and three variables, the degrees of freedom (df) are 79, and at a 5 percent significance level, the critical t-value is 1.664. All path coefficients show T-statistics greater than or equal to 1.664. This result confirms that the relationships between constructs in the structural model are statistically significant, thereby supporting the proposed hypotheses.

3.8. SEM-PLS Path Coefficients and P-Value Analysis

The P-value analysis is conducted to determine the statistical significance of the relationships between constructs and their indicators. In the context of SEM-PLS, a construct is considered valid if the P-value is less than 0.05, indicating that the relationship is statistically significant. Based on the results from SmartPLS, all constructs in the model meet this criterion, with P-values below 0.05. This confirms that each indicator meaningfully contributes to its respective latent construct and supports the structural model's validity. Therefore, these constructs can be reliably used to test the research hypotheses.

3.9. R-Square Values Analysis

The R-Square value, represents the result of the goodness-of-fit test for the outer model. It indicates the proportion of variance in the dependent variable that can be explained by the independent variables. In this study, the R-Square value for the Time (Y) variable is 0.929, with an adjusted R-Square of 0.928, meaning that 92.9 percent of the variance in Time (Y) is explained by the model. Since the adjusted R-Square exceeds the 50 percent threshold, the model's explanatory power is considered strong. Furthermore, other constructs such as X1 an d X2 also show R-Square values above 0.80, indicating that the influence of independent variables on these constructs falls within the moderate to strong category. The results demonstrate that the overall model has good predictive accuracy and validity.

Table 4. R Square and Adjusted R Square Values

No	*Main Factor*	*R Square*	*R Square Adjusted*
1	Collaboration (X1.4)	0,822	0,821
2	Community (X1.3)	0,899	0,898
3	Conservation (X1.11)	0,861	0,860
4	Ecology (X1.12)	0,932	0,931
5	Economy (X1.6)	0,966	0,966
6	Emissions (X1.13)	0,951	0,950
7	Energy (X1.8)	0,908	0,907
8	External (Y1)	0,909	0,908
9	Internal (Y2)	0,923	0,923
10	Lean-Value Stream Mapping (X2)	0,956	0,956
11	Management (X2.5)	0,919	0,918
12	Materials/Resources (X2.2)	0,972	0,972
13	Materials (X1.7)	0,962	0,962
14	Mobility (X1.2)	0,903	0,902
15	Non-Value Added Time (X2.6)	0,916	0,915
16	Construction Implementation (X2.4)	0,986	0,986
17	Planning (X1.5)	0,930	0,929

18	Resilience (X1.14)	0,946	0,945
19	Siting (X1.10)	0,965	0,965
20	Human Resources (X2.3)	0,968	0,968
21	Time (Y)	0,929	0,928
22	Waiting Time (X2.1)	0,886	0,885
23	Water (X1.9)	0,973	0,973
24	Wellbeing (X1.1)	0,900	0,899

3.10. f-Square Values Analysis

The f-square value is used to assess the effect size of each independent variable on the dependent variable in the model. According to Sarstedt et al. (2017), an f-square value of 0.02 indicates a small effect, 0.15 a moderate effect, and 0.35 a large effect. Based on the results shown in Table 5, the majority of constructs in this study exhibit large effect sizes on their respective dependent variables. For instance, the influence of the "Planning" construct on Green Retrofit (X1) shows an f-square of 72.569, while "Materials" (X1.7) contributes an effect size of 35.312. Similarly, "Lean–Value Stream Mapping" (X2) has a notable effect on Time (Y) with a value of 0.362, surpassing the 0.35 threshold. These findings indicate that the independent variables in the model contribute significantly and meaningfully to the prediction of their associated dependent constructs, reinforcing the strength and relevance of the structural relationships within the SEM-PLS framework.

Table 5. *f-Square Values*

No	***Main Factor***	***Time (Y)***	***Green Retrofit (X1)***	***Lean – VSM (X2)***
1	Collaboration (X1.4)		4,632	
2	Community (X1.3)		8,867	
3	Conservation (X1.11)		6,207	
4	Ecology (X1.12)		13,642	
5	Economy (X1.6)		28,489	
6	Emissions (X1.13)		19,296	
7	Energy (X1.8)		9,875	
8	Lean–Value Stream Mapping (X2)	0,362		
9	Management (X2.5)	0,390	21,778	
10	Materials (X2.2)			11,348
11	Materials (X1.7)			35,312
12	Mobility (X1.2)		25,578	
13	Non-Value Added Time (X2.6)		9,319	
14	Construction Execution (X2.4)			10,853
15	Planning (X1.5)			72,569
16	Resilience (X1.14)		13,304	
17	Siting (X1.10)		17,513	
18	Human Resources (X2.3)		27,559	
19	Time (Y)			30,513
20	Waiting Time (X2.1)			
21	Water (X1.9)			7,773
22	Wellbeing (X1.1)		35,795	

3.11. Most Influential Factor Analysis

Based on the analysis of 96 sub-factors, ten key factors were identified as having the strongest influence in determining the success of green retrofitting initiatives toward achieving Envision certification. These factors were ranked by the magnitude of their T-statistic values, where a value greater than 1.664 indicates statistical significance. As shown in Table 6, the most influential factor is "Use of Renewable

Energy" (X1.8.3), with a T-statistic of 645.986 and a strong contribution to the model's R-Square value of 0.929. This is followed by factors such as "Reducing Operational Energy Consumption" (X1.2.2) and "Reducing Operational Waste" (X1.7.3), both of which also exhibit very high levels of significance. The top ten factors predominantly relate to energy use, water management, and emission control, highlighting their crucial role in sustainable jetty development. The findings are further compared with previous studies employing SEM-PLS in green infrastructure research, reinforcing the validity of these results in broader environmental and construction contexts.

Table 6. T-Statistic Analysis Results

No		Sub Factor	Original Sample	Sample Mean	T Statistics >1,664	R Square Contribution
1	X1.8.3	Use of Renewable Energy	0,993	0,993	645,986	
2	X1.2.2	Reduction of Operational Energy Consumption	0,986	0,986	289,306	
3	X1.7.3	Reduction of Operational Waste	0,984	0,984	257,989	
4	X1.8.1	Preservation of Water Resources	0,983	0,983	270,287	
5	X1.9.1	Monitoring of Water Systems	0,978	0,978	187,653	
6	X1.9.4	Stormwater Management	0,975	0,975	172,083	
7	X1.11.1	Reduction of Greenhouse Gas Emissions	0,965	0,965	103,263	0,929
8	X1.12.2	Enhancement of Wetlands and Surface Water Function	0,964	0,964	119,204	
9	X1.13.2	Reduction of Air Pollutant Emissions	0,959	0,959	107,024	
10	X1.13.3	Promotion of Sustainable Transport	0,957	0,957	129,068	

3.12. Case Study Analysis

This section elaborates on the application of green infrastructure principles in the retrofitting of an existing jetty project. The analysis is based on data obtained through a structured assessment and focuses on aligning the project with the Envision Sustainable Infrastructure framework. The study begins with the evaluation of the jetty's current condition, followed by the identification of retrofit strategies, estimation of the required implementation time, and optimisation of the schedule using lean value stream mapping (VSM). According to Espinoza (2021), lean VSM has the potential to improve time efficiency by up to 17 per cent in construction projects [32].

The object of the study is a naval jetty operated by the Indonesian Navy's Koarmada III, located in Sorong, West Papua. The jetty spans 300 by 20 metres and includes three trestles each measuring 60 by 11 metres, capable of accommodating vessels with a displacement of 12,000 DWT. The total contract value was IDR 299,137,449,000.00 and the project was completed over 644 calendar days.

An initial sustainability assessment was conducted using the Envision framework. The framework assigns infrastructure a sustainability rating of Verified, Silver, Gold or Platinum, based on the percentage of credits achieved from a total of 1,000 points. The initial condition assessment of the existing jetty yielded a score of only 149 points, or 14.9 per cent, placing it within the "No Level Achieved" category. In order to upgrade the infrastructure to green standards, several retrofit components were identified, including solar panel installation, shore power connection, water treatment systems, and waste management facilities.

Table 7. Duration Requirements for Green Retrofit Jetty Implementation

No	Green Retrofitting Plan	Verified (days)	Silver (days)	Gold (days)	Platinum (days)
1	Installation of 550 WP Polycrystalline Solar Panels			215	250
2	Shore Power Connection			41	54
3	Water Treatment Plant		90	90	108
4	Integrated Waste Disposal Facility	24	24	24	24
5	Retention Tank	45	45	45	45
6	Public Transport Shelter	24	24	24	24
7	Public Electric Vehicle Charging Station (EVCS)	24	24	24	24
8	Landscaping Work	6	6	6	6
	Total Time Required	**45**	**90**	**215**	**250**

The retrofit plan to achieve Platinum certification would require 250 days, while Gold and Silver would require 215 days and 90 days respectively.

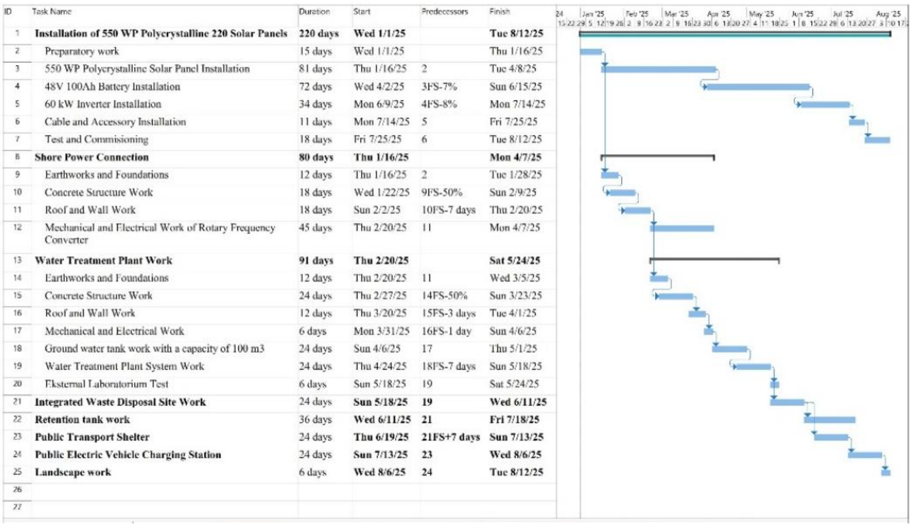
Despite the low initial sustainability score, the project demonstrates considerable potential for improvement through targeted interventions. Government regulations and policy incentives are recognised as key enablers for the adoption of green infrastructure, as reflected in stakeholder feedback. Furthermore, the competence of project managers plays a vital role in achieving sustainable outcomes, especially when supported by explicit policy directives such as green building regulations and licensing conditions.

The Envision assessment was conducted in accordance with the official guidelines developed by the Institute for Sustainable Infrastructure (ISI). The final rating is determined through a certified process, with scoring weighted according to the significance of each category.

Table 8. Example of Envision Scoring and Rating Calculation

Envision Section	Credit Achieved	Credit Available	% of Credit Achieved	Category Weighting	Section Score (%)
	A	**B**	**(A:B)**	**C**	**(A:B) x C**
Quality of Life	76	200	38,00	0,15	5,46
Leadership	90	182	49,45	0,19	9,56
Resource Allocation	120	196	61,22	0,24	14,65
Natural World	79	232	34,05	0,13	4,53
Climate and Resilience	139	190	73,16	0,29	20,92
Innovation (additional)	-	50	0,00	-	-
Final Envision Point	504	1.000			55,30
Envision Rating					***PLATINUM***

As shown in the scoring, a total of 55,3 per cent qualifies the jetty for a Platinum rating. This is further supported by an optimised schedule.



ID	Task Name	Duration	Start	Predecessors	Finish
1	**Installation of 550 WP Polycrystalline 220 Solar Panels**	**220 days**	**Wed 1/1/25**		**Tue 8/12/25**
2	Preparatory work	15 days	Wed 1/1/25		Thu 1/16/25
3	550 WP Polycrystalline Solar Panel Installation	81 days	Thu 1/16/25	2	Tue 4/8/25
4	48V 100Ah Battery Installation	72 days	Wed 4/2/25	3FS-7%	Sun 6/15/25
5	60 kW Inverter Installation	34 days	Mon 6/9/25	4FS-8%	Mon 7/14/25
6	Cable and Accessory Installation	11 days	Mon 7/14/25	5	Fri 7/25/25
7	Test and Commisioning	18 days	Fri 7/25/25	6	Tue 8/12/25
8	**Shore Power Connection**	**80 days**	**Thu 1/16/25**		**Mon 4/7/25**
9	Earthworks and Foundations	12 days	Thu 1/16/25	2	Tue 1/28/25
10	Concrete Structure Work	18 days	Wed 1/22/25	9FS-50%	Sun 2/9/25
11	Roof and Wall Work	18 days	Sun 2/2/25	10FS-7 days	Thu 2/20/25
12	Mechanical and Electrical Work of Rotary Frequency Converter	45 days	Thu 2/20/25	11	Mon 4/7/25
13	**Water Treatment Plant Work**	**91 days**	**Thu 2/20/25**		**Sat 5/24/25**
14	Earthworks and Foundations	12 days	Thu 2/20/25	11	Wed 3/5/25
15	Concrete Structure Work	24 days	Thu 2/27/25	14FS-50%	Sun 3/23/25
16	Roof and Wall Work	12 days	Thu 3/20/25	15FS-3 days	Tue 4/1/25
17	Mechanical and Electrical Work	6 days	Mon 3/31/25	16FS-1 day	Sun 4/6/25
18	Ground water tank work with a capacity of 100 m3	24 days	Sun 4/6/25	17	Thu 5/1/25
19	Water Treatment Plant System Work	24 days	Thu 4/24/25	18FS-7 days	Sun 5/18/25
20	Eksternal Laboratorium Test	6 days	Sun 5/18/25	19	Sat 5/24/25
21	**Integrated Waste Disposal Site Work**	24 days	**Sun 5/18/25**	**19**	**Wed 6/11/25**
22	**Retention tank work**	36 days	**Wed 6/11/25**	**21**	**Fri 7/18/25**
23	**Public Transport Shelter**	24 days	**Thu 6/19/25**	**21FS+7 days**	**Sun 7/13/25**
24	**Public Electric Vehicle Charging Station**	24 days	**Sun 7/13/25**	**23**	**Wed 8/6/25**
25	**Landscape work**	6 days	**Wed 8/6/25**	**24**	**Tue 8/12/25**
26					
27					

Figure 6. Time schedule envision rating platinum

In conclusion, this case study demonstrates a practical pathway for transforming conventional port infrastructure into a sustainable asset. The Envision framework facilitates structured and objective decision-making, while the application of lean construction methods ensures efficient use of time and resources. Together, these approaches contribute to the broader agenda of advancing sustainable infrastructure within the maritime sector.

3.13. Influential Factors in Green Retrofit Jetty

The results of the SEM-PLS analysis identified ten key sub-factors that significantly influence the success of green retrofit implementation in sustainable jetty projects, based on Envision certification standards. The most dominant factor was Use Renewable Energy, with the highest t-statistic value of 645.986 and an original sample loading of 0.993. This demonstrates a strong contribution to the Green Retrofit (X1) variable, emphasising that energy transition is a critical element in green infrastructure development. This finding is consistent with [27], who noted that the integration of renewable energy enhances environmental performance in construction projects.

Other significant factors include Reducing Operational Energy Consumption, Reducing Operational Waste, Preserving Water Resources, and Managing Stormwater, all of which contribute directly to the adoption of environmentally responsible practices in port infrastructure. These results are aligned with the core principles of the Envision framework, which prioritises resource conservation, pollution reduction, and long-term resilience.

Collectively, the findings indicate that commitment to energy efficiency, waste minimisation, and ecological protection plays a crucial role in achieving higher green retrofit ratings, such as the Platinum level under Envision. Implementing these ten factors allows existing conventional jetties to transform into environmentally friendly infrastructure, better prepared to face climate challenges and optimise long-term operational outcomes.

3.14. Implementation of Lean-Value Stream Mapping (VSM)

To enhance project execution efficiency, Lean Value Stream Mapping (VSM) was applied in the Green Retrofit Jetty project. This method aimed to visualise all project activities and identify non-value-added (NVA) elements that caused delays or inefficiencies. The analysis concentrated on a critical task, namely the installation of solar panels, which forms a key part of the renewable energy strategy. The implementation began with the development of a Work Breakdown Structure (WBS), followed by task sequencing and duration estimation, based on data from a comparable completed project.

The mapping process categorised 31 per cent of activities as Value Added (VA), 44 per cent as Essential Non-Value Added (ENVA), and 25 per cent as Non-Value Added (NVA). NVA activities, such as redundant documentation, idle material handling, and excessive equipment movement, were subsequently targeted for elimination or minimisation.

Subsequently, both a Current State Map (CSM) and a Future State Map (FSM) were produced to illustrate the project workflow before and after lean optimisation. The implementation of VSM resulted in a reduction of 30 days in project duration, cutting the timeline from 250 days to 220 days. This result clearly demonstrates the effectiveness of VSM in optimising project delivery without compromising quality standards.

A fishbone diagram analysis was also conducted to explore the root causes of inefficiencies, focusing on aspects such as materials, methods, manpower, and machinery. The most frequently observed forms of waste included unnecessary processing, excessive inventory, waiting times, and inefficient transportation. These findings align with the eight categories of waste defined in Lean Construction theory, as established by Womack and Jones (2003) [33].

In conclusion, the integration of green infrastructure principles, as prescribed by the Envision framework, with lean construction methods through VSM, offers a practical and effective strategy for enhancing the sustainability and time efficiency of jetty infrastructure projects. The results provide useful insights for stakeholders aiming to implement similar sustainable construction practices and contribute meaningfully to the advancement of environmentally responsible maritime infrastructure.

4. Conclusion

This study concludes that the integration of green retrofit principles guided by the Envision framework and optimised through Lean Value Stream Mapping (VSM) significantly improves time performance in sustainable jetty construction. The findings clearly address the research objectives and questions stated at the beginning.

First, ten key factors were identified as the most influential in enhancing time efficiency through lean-VSM application in the context of a green retrofit jetty. These factors include the use of renewable energy, reduction of operational energy and waste, conservation and monitoring of water resources, stormwater management, reduction of greenhouse gas and air pollutant emissions, enhancement of wetland and surface water functions, and promotion of sustainable transportation.

Second, the study confirms that the Envision framework is an effective tool for guiding the planning and implementation of green retrofit infrastructure. Its structured assessment allows project teams to systematically evaluate sustainability performance and align their interventions with recognised rating levels such as Verified, Silver, Gold or Platinum.

Third, the application of lean-VSM has proven effective in identifying and eliminating non-value-adding activities. In this study, the retrofit schedule required to meet the Envision Platinum rating was shortened from 250 days to 220 days, resulting in a time efficiency gain of 12 per cent.

Future research may explore the integration of digital construction tools to further enhance the effectiveness of lean and green practices. Comparative studies on different infrastructure types such as bridges, ports, or transport terminals could also help generalise the findings and expand the applicability of the combined Envision and lean approach.

References

[1] McFarlane KJ, Cusack DF, Dietterich LH, Hedgpeth AL, Finstad KM, Nottingham AT. Experimental warming and drying increase older carbon contributions to soil respiration in lowland tropical forests. Nat Commun 2024;15:7084 DOI: 10.1038/s41467-024-51422-6.

[2] Hidayah S, Husin AE. Retrofitting healthcare facility based on regulation of green performance assessment in Indonesia. AIP Conf Proc, vol. 2710, AIP Publishing LLC; 2024, p. 90018.

[3] Priyawan, Husin AE. Zero Emission Guide by The Last Indonesian Minister Regulation of 2022 Uses Blockchain–BIM for Green Efficiency. Rekayasa Sipil 2024;18:55–65 DOI: 10.21776/ub.rekayasasipil.2024.018.01.10.

[4] Fitri R, Caisarina I. Pengaruh Green Infrastructure Terhadap Perencanaan Progam Inisiasi Green City Banda Aceh 2023: The Influence of Green Infrastructure on the Planning of the Green City Banda Aceh 2023 Initiation Program. Rumoh Journal of Architecture 2022;12:1–8 DOI:10.37598/sttt1n14.

[5] Firmawan F, Kuncoro AHB, Budiningrum DS. Implementasi Green Construction Pada Proyek Konstruksi Pembangunan Bendungan Jragung, Semarang. Jurnal Teknik Sipil 2023;19:293–307 DOI:10.28932/jts.v19i2.6396.

[6] Busono T, Rahmanisa HO, Surahman U, Mulyadi Y, Setiawan W. Implementation of the greenship rating tools in the Centre of Excellent (CoE) building at Universitas Pendidikan Indonesia. IOP Conf Ser Earth Environ Sci, vol. 738, IOP Publishing; 2021, p. 12040 DOI 10.1088/1755-1315/738/1/012040.

[7] Karimi S, Piroozfar P. Exploring Causes of Delays in National Road and Highway Projects in Developing Construction Economy. Journal of Engineering, Project, and Production Management 2022;12:137 DOI:10.32738/JEPPM-2022-0013.

[8] Hwang B-G, Zhu L, Wang Y, Cheong X. Green building construction projects in Singapore: Cost premiums and cost performance. Project Management Journal 2017;48:67–79 DOI:10.1177/875697281704800406.

[9] Fei W, Opoku A, Agyekum K, Oppon JA, Ahmed V, Chen C, et al. The critical role of the construction industry in achieving the sustainable development goals (SDGs): Delivering projects for the common good. Sustainability 2021;13:9112 DOI:10.3390/su13169112.

[10] Martínez-Falcó J, Marco-Lajara B, Sánchez-García E, Millán-Tudela LA. Green Supply Chain Management Practice and Principles. IGI Global; 2024 DOI:10.6007/IJARBSS/v14-i12/24075.

[11] Javed S, Hussain MI, Al Aamri AM, Akhtar J. Investigation on factors causing construction delay and their effects on the development of Oman's construction industry. EUREKA: Physics and Engineering 2022;3:33–44 DOI:10.21303/2461-4262.2022.001865.

[12] Oz B. A non-price-based tender evaluation methodology considering tenderers' self-confidence with partial value functions and time decay analysis. Expert Syst Appl 2024;252:124186 DOI:10.1016/j.eswa.2024.124186.

[13] Sabah A, Al-Kindi L, Al-Baldawi Z. Adopting value stream mapping as a lean tool to improve production performance. Eng Technol J 2023;41:1–14 DOI:10.30684/etj.2023.136269.1307.

[14] Gohel P, Dabral R, Lad VH, Patel KA, Patel DA. A comprehensive review on application of artificial intelligence in construction management using a science mapping approach. Artificial Intelligence Applications for Sustainable Construction 2024:285–300 DOI:10.1016/B978-0-443-13191-2.00006-7.

[15] Fitriadi F, Mohamad Ayob AF. Optimizing Traditional Shipyard Industry: Integrating VSM and Sustainability Indicators for Continuous Improvement. Journal of Advanced Research in Applied Sciences and Engineering Technology 2025 DOI:10.22094/JOIE.2023.1982419.2052.

[16] Espinoza LR, Herrera RF, Brioso X. Use Of Value Stream Mapping In A Case Study In Basement Construction. IGLC 2021 - 29th Annual Conference of the International Group for Lean Construction - Lean Construction in Crisis Times: Responding to the Post-Pandemic AEC Industry Challenges, Department of Engineering, Civil Engineering Division, Pontificia Universidad Catolica del Peru; 2021, p. 995–1004. DOI:10.24928/2021/0189.

[17] Supriyono AS, Putra INDP, Trigunarsyah B. Comparative Analysis of Formwork Systems: Cost Efficiency and Time Management in Construction Projects. Advance Sustainable Science Engineering and Technology 2025;7:250204 DOI:10.26877/asset.v7i2.1320.

[18] Ahmad F, Al-Odaini AA, Inamdar MN, Naeem MM, Omair M, Rafiq H, et al. Sustainable Strengthening of Concrete Using Lathe Waste Steel Fibers: Experimental and FEA Analysis: Sustainable Fiber Reinforced Concrete. Advance Sustainable Science Engineering and Technology 2025;7:250205 DOI:10.26877/asset.v7i2.1068.

[19] Sinulingga IDB, Rusindiyanto. Analysis of Lean Manufacturing Using the Waste Assessment Model (WAM) to Reduce Waste in the Bolt Production Process at PT. XYZ. Advance Sustainable Science Engineering and Technology 2025;7:250105 DOI:10.26877/asset.v7i1.699.
[20] Lestari ADA, Pulansari F. Environmental Impact Analysis on Furniture Industry by Implementing Life Cycle Assessment (LCA) Method. Advance Sustainable Science Engineering and Technology 2025;7:250106 DOI:10.26877/asset.v7i1.747.
[21] Farichah H, Hutama DA, Alextrianto V, Satyanaga A, Ghifari F. Numerical Investigation of Consolidation Settlement for Runway Construction on Soft Soil: A Case Study in Sumbawa, Indonesia. Advance Sustainable Science Engineering and Technology 2025;7:250304 DOI: 10.26877/asset.v7i3.1805.
[22] Bordignon F, Maisonobe M. Researchers and their data: A study based on the use of the word data in scholarly articles. Quantitative Science Studies 2022;3:1156–78 DOI: 10.1162/qss_a_00220.
[23] Shishodia A, Sharma R, Rajesh R, Munim ZH. Supply chain resilience: A review, conceptual framework and future research. The International Journal of Logistics Management 2023;34:879–908 DOI:10.1108/IJLM-03-2021-0169.
[24] Chandrakar VKS, Jain AD. Efficient Construction by Implementation of Lean Management Principles. International Journal of Scientific Research in Civil Engineering 2019;3:20–5.
[25] Sudaryana B, Agusiady HRR. Metodologi penelitian kuantitatif. Deepublish; 2022.
[26] Becker J-M, Cheah J-H, Gholamzade R, Ringle CM, Sarstedt M. PLS-SEM's most wanted guidance. International Journal of Contemporary Hospitality Management 2023;35:321–46. DOI:10.1108/IJCHM-04-2022-0474.
[27] Hair JF, Hult GTM, Ringle CM, Sarstedt M. A Primer On Partial Least Squares Structural Equation Modeling (PLS-SEM). Second Edition. London: SAGE Publications, Inc; 2017.
[28] Ghozali I, Latan H. Partial Least Squares Konsep, Teknik dan Aplikasi Menggunakan Program Smart PLS 3.0 Edisi 2 (Untuk Penelitian Empiris). Semarang: Badan Penerbit Universitas Diponegoro Semarang; 2015.
[29] Wong KK-K. Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. Marketing Bulletin 2013;24:1–32.
[30] Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. J Acad Mark Sci 2015;43:115–35.
[31] Hair J, Hult GTM, Ringle C, Sarstedt M. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). 2022. DOI:/10.1007/978-3-030-80519-7.
[32] Espinoza LR, Herrera RF, Brioso X. Use of value stream mapping in a case study in basement construction 2021.
[33] Womack JP, Jones DT. Banish waste and create wealth in your corporation. Recuperado de http://www.kvimis.co.in/Sites/Kvimis Co in/Files/Ebook_attachments/James 2003;56.