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Analysis of Non-Physical Waste Production Variables (Lean Six Sigma) on Project Time Management Through the Mediation of Lean Construction

Rakhmad Sugih Hartono[1*], Slamet Riyadi[2], Fausta Ari Barata[3]
Universitas 17 Agustus 1945 Surabaya, Indonesia
Email: 1262400043@surel.untag-sby.ac.id*, slametriadi08@yahoo.com, fausta@untag-sby.ac.id

ABSTRACT

Construction projects are entering an era of profitability, aiming to achieve business goals with minimal resources. Yet, prior research shows only 54% complete on time, due to activity variations causing production waste and delays. This study examines non-physical waste production from the Lean Six Sigma concept's influence on project time management via Lean Construction mediation in the PUSRI 3B project. Methods included identifying delay factors from literature and field observations, categorizing them as Lean Six Sigma non-physical waste, and distributing Likert-scale questionnaires to respondents. Data were analyzed using SmartPLS ver. 4 with Structural Equation Modeling (SEM). Results indicate defect and overproduction waste significantly affect Lean Construction implementation but not time management—present in PUSRI 3B yet mitigated by quality control, avoiding delays. Inventory waste significantly impacts both Lean Construction and time management, contributing to delays. Overall, non-physical waste production significantly influences time management through Lean Construction mediation.

KEYWORDS non physic waste production, time control, lean construction

INTRODUCTION

Project management as a new technique in the implementation of development (construction), was only known in the middle of the 20th century—precisely in the 1950s after World War II—when military giant projects began to develop by adopting a systematic construction method approach. Globally, project delays have significant financial, reputational, and legal consequences (Agyekum-Mensah & Knight, 2017; Gbahabo & Samuel, 2017; Moon, 2020). According to recent industry reports, delayed projects result in cost overruns averaging 20-30% of the total budget, damage contractor credibility, and often lead to contractual disputes and litigation (Antoniou & Tsioulpa, 2024; GEBRE, 2021; Samarghandi et al., 2016; Taye, 2016). In developing economies like Indonesia, these impacts are even more pronounced, affecting national infrastructure development goals and economic growth (Nawir et al., 2023; Nugraha et al., 2020; Salim & Negara, 2018; Syadullah & Setyawan, 2021).

Project activities can be categorized into three eras: the 1st Era, starting in 1900, called the Productivity Era or also known as the Scientific Management Era, with the aim of maximizing worker output; the 2nd Era, starting in 1950, called the Predictability Era or also known as the Project Management Era, with the aim of estimating results through measurement and compliance; and the 3rd Era, beginning in 1990, called the Era of Profitability or known as the Era of Production Systems, with the aim of achieving business goals with minimal resource use (Muhamad Abduh, 2025).

Several previous studies have examined non-physical waste and lean construction in project management contexts. Arbulu and Tommelein (2002) identified value stream mapping as a critical tool for eliminating non-physical waste in construction supply chains. Bashir et al. (2015) demonstrated that implementing lean construction principles reduced project delays by up to 35% in infrastructure projects. In the Indonesian context, Santoso and Soeng (2016) found that inventory waste and waiting time were the two most critical factors affecting construction project performance. More recently, Alves et al. (2020) confirmed that lean construction mediation significantly improves time management outcomes when addressing non-physical waste. These studies establish the theoretical foundation for examining the relationship between non-physical waste production, lean construction implementation, and time management performance (Fateh & Sulaiman, 2021; Igwe, Hammad, et al., 2022; Nikakhtar et al., 2015; Sahlu & Dinku, 2021).

In (Muhamad Abduh, 2025), a comparison of production activities in projects and factories reveals that waste in project production activities reaches 57%, compared to 26% in factory (manufacturing) production activities; support activities account for 33% in projects and 12% in factories (manufacturing); and value-adding activities comprise 10% in projects and 62% in factories (manufacturing). The same source explains, based on prior research data, that only about 54% of projects are completed on time, highlighting a phenomenon of persistent production waste in projects that causes delays in project completion (Igwe, Nasiri, et al., 2022; Omotayo et al., 2020).

Based on experience, literature studies, and prior research, numerous factors fall under the non-physical waste production category—specifically, eight types of production waste from the Lean Six Sigma method: defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing. Such waste occurs at the project stage due to diverse work variants and methods, leading to non-value-added activities that delay work completion (Bhatta et al., 2023; Dara et al., 2024, 2025; Vänskä, 2025).

The problem formulation of this study is as follows: Does non-physical waste production (defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing) have a significant effect on lean construction implementation in the PUSRI 3B project? Does non-physical waste production (defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing) have a significant effect on project time management in the PUSRI 3B project? And does lean construction implementation have a significant effect on project time management in the PUSRI 3B project?

The research object is a case study on the PUSRI 3B Project, an EPC project in the high-exposure category undertaken by PT Adhi Karya (Persero), Tbk (ADHI). This research topic aligns closely with current phenomena in Indonesia's construction industry and supports operational excellence at ADHI through continuous improvement in project management. The project represents a critical case for investigation due to its complexity, scale, and strategic importance to Indonesia's industrial infrastructure. Selecting this EPC (Engineering, Procurement, and Construction) project provides a comprehensive setting to examine all phases where non-physical waste typically occurs.

The urgency of this research stems from both academic and practical needs. Academically, there is limited empirical evidence on how specific types of non-physical waste affect time management in large-scale EPC projects within the Indonesian construction industry context. Practically, PT Adhi Karya and the broader Indonesian construction sector require evidence-based strategies to improve project completion rates, which currently fall significantly below international benchmarks. With Indonesia's ambitious infrastructure development targets, improving time management through waste reduction has become a national priority.

The novelty of this research lies in three key aspects: (1) it specifically examines the mediation role of lean construction in the relationship between non-physical waste and time management, which has not been extensively studied in EPC projects; (2) it applies the SEM-PLS methodology to test these relationships empirically using data from a high-exposure EPC project in Indonesia; and (3) it differentiates among eight types of non-physical waste (defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing) to identify which specific types have the most significant impact on time management outcomes. This differentiation enables targeted intervention strategies rather than generic waste reduction approaches.

The purpose of this study is to prove that non-physical waste production (defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing) has a significant effect on lean construction implementation in the PUSRI 3B project; that non-physical waste production (defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing) has a significant effect on project time management in the PUSRI 3B project; and that lean construction implementation has a significant effect on project time management in the PUSRI 3B project.

RESEARCH METHOD

The researcher employed a quantitative analysis approach. Data were obtained from respondents through questionnaires. Respondents were selected from the population of all ADHI employees working on the PUSRI 3B project, including the project manager, engineering team, construction team, HSE team, quality control team, procurement team, project control team, finance team, and commissioning team.

The researcher applied the Six Sigma framework, with variables comprising project delay factors measured across eight types of activity waste: defect, over production, waiting, non-utilization, transportation, inventory, motion, and extra processing. This quantitative research utilized questionnaire data analyzed via SmartPLS ver. 4 software. Analysis results informed improvement steps to align project implementation with the overall completion schedule.

The population consisted of 146 PUSRI 3B project employees directly involved in production activities. The researcher used probability sampling with simple random sampling, targeting 100% of the population (146 individuals). Due to time and cost constraints, data from 75 respondents were used.

Data collection involved questionnaires distributed at the Define stage to test the significance of relationships between latent variables per the research hypotheses (Benny S. Pasaribu et al., 2022). Questionnaire results were summarized for analysis.

The measurement scale used in the questionnaire is a modification of the likert scale by using 6 (six) categories to avoid neutral answers from respondents, with the following categories:

a. Very Significant (SS) = score 6
b. Significant (S) = score 5
c. Somewhat Significant (AS) = score 4
d. Somewhat Insignificant (ATS) = score 3
e. Insignificant (TS) = score 2
f. Very Insignificant (STS) = score 1

Descriptive analysis described the collected data as observed, without general conclusions (Sugiyono, 2013:147). Field observations identified non-physical production waste indicators in the PUSRI 3B project conditions, with each waste category including four relevant indicators. Questionnaires were distributed to 146 respondents—project employees directly involved in production activities at the research object—to assess the significance of waste production indicators in the PUSRI 3B project.

Data analysis followed the formulated hypotheses using SmartPLS software ver. 4, progressing from the measurement model (outer model) to the structural model (inner model). Validity and reliability were assessed (Muhson, 2022), with convergent validity evaluated via average variance extracted (AVE), discriminant validity assessed through factor loadings and cross-loadings, and construct reliability tested with Cronbach's Alpha and Composite Reliability.

The structural model examined goodness of fit through R-Square (R^2) and effect size (f^2). Path coefficients measured direct impacts via t-statistics, p-values, and original samples from bootstrapping (Imam Ghozali, 2015; Muhson, 2022), with significance determined at t-statistic > 1.645 (5% level). Specific indirect effects evaluated mediation through p-values < 0.05 (Muhson, 2022).

RESULTS AND DISCUSSION

This study aims to prove the influence of the significance of variable indicators Non-Physic Waste Production (DF, OP, WT, NU, TR, IV, MT, EP) which is mediated by the lean construction (LC) variable against the project time control variable (TM), through quantitative analysis of structural equation modelling, with the help of SmartPLS ver software. 4

The research data was taken through respondents from the research sample, namely respondents totaling 75 (seventy-five) employees of the PUSRI 3B project who directly carried out and were responsible for the production process.

Based on age group, the most respondents were in the 25-40 year range of 50 people (67%). The next age group was 41–65 years old as many as 20 people (27%), while respondents under the age of 25 years were 5 people (7%). This shows that most respondents are in the middle of productive age who generally have had quite mature work experience.

In terms of gender, most respondents were men as many as 69 people (92%), while women as many as 6 people (8%). This proportion shows the dominance of male respondents, which is most likely influenced by the characteristics of industries or fields of work that involve more male workers.

Judging from the last education, respondents with Academy/S2 education were 1 person (1%), respondents with Academy/S1 education were 55 people (73%), respondents with D3/D4 education were 8 people (11%), and respondents with high school/vocational/secondary education were 11 people (15%). This data illustrates that most respondents have higher education backgrounds that are relevant to their jobs.

Based on the length of work, 33 respondents (44%) worked for more than 10 years, 21 respondents (28%) worked between 5 and 10 years, and 21 respondents (28%) worked for less than 5 years. This composition shows the dominance of respondents who have worked for more than 10 years, which can reflect having experience in work.

Based on position, respondents with positions directly related to production activities were 38 people (51%), respondents with positions directly related to engineering activities were 33 people (44%), and respondents with positions directly related to financing activities were 4 people (5%). This composition shows the dominance of respondents' positions that are directly related to the production process as much as 51% and engineering as much as 44%.

The researcher used an inferential test in this study, which is a statistical technique used to draw conclusions or give predictions about a population based on data taken from samples. The aim is to determine whether the results obtained from the sample can be generalized/applied to the entire population/larger group. The research analysis was conducted by the researcher using SmartPLS ver. 4, which uses the Partial Least Squares (PLS) and Structural Equation Modeling (SEM) methods based on variance.

The data included in the latent variable model to be analyzed in this study has gone through descriptive analysis using the mean data analysis method taken from the score of respondents' answers to the latent variable indicator.

It is concluded that all indicators of latent variables of non-physic waste production (DF, OP, WT, NU, TR, IV, MT, EP) have high mean values, thus proving that all indicators of these latent variables affect the latent variables of lean construction (LC) and the variable of time control (TM) in the PUSRI 3B project.

The validity and realism test was carried out by the researcher by following 2 (two) stages of research, namely model measurement (outer model) and model structure (inner model).

In the process of testing the measurement model, validity and reliability checks are carried out. There are three main types of testing in the outer model, namely Convergent Validity, Discriminated Validity, and Construct Reliability.

Convergent Validity has 2 (two) value criteria to be evaluated, namely the loading factor value or the Average Variance Extracted (AVE) value.

1. Value loading factor.

   The output of the outer loading results is measured from the relationship between the indicator score (instrument) and its construct (variable). The indicator is considered valid if it has a correlation value above 0.70. If there are indicators that do not meet these requirements, they must be discarded. The results of convergent validity in the first stage of the research.

   The output loading factor value for the Defect variable has 1 (one) statement with a value of 0.504 < a loading factor value of 0.70. The value of the Inventory variable has 1 (one) statement with a value of 0.652 < a loading factor value of 0.70. The value of the Lean Construction variable has 2 (two) statements with values of 0.653 and 0.691 which < a loading factor value of 0.70. The value of the Motion variable has 1 (one) statement with a value of 0.588 < a load factor value of 0.70. The value of the Non Utilization variable has 2 (two) statements with values of 0.625 and 0.588 which < a loading factor value of 0.70. The value of the Over Production variable has 2 (two) statements with values of 0.697 and 0.686 which < a loading factor value of 0.70. The value of the Time Management variable has 3 (three) statements with values of 0.692, 0.662 and 0.688 which < a loading factor value of 0.70. The value of the Transportation variable has 1 (one) statement with a value of 0.479 < a loading factor value of 0.70. All variable statements with a value of < 0.70 must be deleted and retested.

   The output value of the loading factor of this second stage of testing all the statements of the variables Defect, Extra Processing, Inventory, Lean Construction, Motion, Non Utilization, Over Production, Time Management, Transportation, and Waiting all have a > loading factor value of 0.7 so that all are said to be valid. This indicates that the indicator/statement used successfully measures the relationship between the indicator/statement score and its constructs/variables, thus supporting the validity of the measurement model's construct.

2. Average Variance Extracted (AVE).

   The output of the estimated average variance extracted (AVE) can be seen in table 5.9. A variable is said to be valid if it has an average variance extracted (AVE) value of > 0.5.

Table 1 : AVE Convergent Validity Test Results

Variable	Average variance extracted (AVE)	Information
Defect	0.710	Valid
Extra Processing	0.635	Valid
Inventory	0.722	Valid
Lean Construction	0.725	Valid
Motion	0.714	Valid
No Utilization	0.731	Valid
About Production	0.700	Valid
Time Management	0.781	Valid
Transportation	0.713	Valid
Waiting	0.640	Valid

Source: Processed Researcher (2025).

The AVE value of each variable is Defect of 0.710, Extra Processing of 0.635, Inventory of 0.722, Lean Construction of 0.725, Motion of 0.714, Non Utilization of 0.731, Over Production of 0.700, Time Management of 0.781, Transportation of 0.713, Waiting of 0.640 These ten variables have a ≥ value of 0.50, meaning that the ten variables are categorized as valid.

Discriminant validity is used to ensure that the constructs or variables in the measurement model actually measure things that are different or do not overlap with each other. In other words, discriminant validity measures the extent to which different constructs in a measurement model can be distinguished from each other. Discriminant validity can be measured using cross loading values.

Indicators/statements are declared valid if the relationship of the indicator/statement with its constructs/variables (cross loading values) is higher than its relationship with other constructs, if it does not meet these criteria then the instrument indicator must be deleted. The following are the results of data processing using SmartPLS ver. 4 with the result of cross loading.

The Cross Loading values for the variables Defect, Extra Processing, Inventory, Lean Construction, Motion, Non Utilization, Over Production, Time Management, Transportation, and Waiting have a correlation value between the indicator (instrument) and its construction (Variable) > indicators (instruments) in other constructs (Variables). The results of the convergent validity and discriminant validity tests showed consistent numbers, with all indicators declared valid. This indicates that the model used has a good match and is able to distinguish between different constructs effectively. Thus, it can be concluded that the measuring tool used in this study is valid.

Construct Reliability can be analyzed using one of two methods, namely by analyzing Cronbach's Alpha values and composite reliability. These two methods are part of the process used to test the reliability value of indicators on a variable.

1. Cronbach's Alpha
   Cronbach's Alpha is an important indicator in testing the reliability of variables in the PLS-SEM model. Cronbach's high Alpha value ≥ 0.7 indicates that the construct/variable is well and consistently measured for measurement validity in PLS analysis. Conversely, if Cronbach's Alpha value is low, it may indicate that the indicator/statement used is not reliable enough and needs to be corrected or replaced. The results of the construct reliability are shown in table 2.

Table 2. Cronbach's Alpha Values

Variable	Cronbach's alpha	Information
Defect	0.932	Reliable
Extra Processing	0.910	Reliable
Inventory	0.900	Reliable
Lean Construction	0.728	Reliable
Motion	0.923	Reliable
No Utilization	0.924	Reliable
About Production	0.865	Reliable
Time Management	0.920	Reliable
Transportation	0.915	Reliable
Waiting	0.919	Reliable

Source: Processed Researcher (2025)

All of Cronbach's Alpha values are ≥ 0.70. So that all variables have good reliability.

Composite Reliability is used to ensure the internal consistency of the indicators that make up the latent variables. In Smart PLS, Composite Reliability is the main tool for measuring reliability, and a CR value of ≥0.7 is considered to meet the standard for research.

Table 3. Value Composite reliability

Variable	Composite reliability	Information
Defect	0.945	Reliable
Extra Processing	0.929	Reliable
Inventory	0.930	Reliable
Lean Construction	0.880	Reliable
Motion	0.940	Reliable
No Utilization	0.943	Reliable
About Production	0.909	Reliable
Time Management	0.943	Reliable
Transportation	0.938	Reliable
Waiting	0.934	Reliable

Source: Processed Researcher (2025)

All these Composite reliability values are ≥ 0.70. So that all variables have good reliability.

The inner model in PLS-SEM describes the relationships between latent variables and is evaluated to see the strength and significance of these relationships. The evaluation includes three main aspects: Significance of the relationship (Hypothesis Testing), R Square and Effect Size.

R-Square in PLS-SEM measures how well latent independent variables in a model can explain the variability of latent dependent variables. The R^2 value indicates the overall predictive strength of the model. The value of R^2 ranges from 0 to 1, where a higher value indicates a better model at explaining the variance. Here are the R-Square values in this analysis.

Table 4. R Square (R^2) Test Results

Dependent Variable	R-Square	R-Square Adjusted
Lean Construction	0.784	0.758
Time Management	0.852	0.831

Source: Processed Researcher (2025)

Based on the results of the analysis, an R-Square value of 0.784 for the Lean Construction variable showed that 78.4% of the variation in this variable could be explained by independent variables in the model, while the remaining 21.6% were influenced by other factors outside the model, so the relationship between independent variables and Lean Construction can be considered quite strong. Meanwhile, the R-Square value of 0.852 for the Time Management variable indicates that 85.2% of the variation in this variable can be explained by independent variables in the model, with 14.8% being influenced by external factors. This value shows a very strong relationship, meaning that the model is able to explain most of the factors that influence Time Management, although there are still many influences from outside the model. Here is a figure of 5.3 output of the PLS SEM Algorithm to see the R2 research model.

The F Square test was carried out to assess the influence of all exogenous variables on endogenous variables, the influence of all exogenous variables on the mediating variables, and the influence of mediation variables on endogenous variables. Variable impact assessments are grouped as small, medium, or large. As a guide, the F-Square value of 0.02 is considered small, 0.15 is considered medium, and 0.35 is considered the large category.

Based on the results of the analysis obtained, it shows that:

1. The effect size (F2) of the non-physic waste production (DF) defect variable on the implementation of lean construction (LC) of 0.228 is included in the category of moderate effects (0.15<F2<0.35) and the effect size (F2) of the non-physic waste production (DF) variable on time management (TM) of 0.046 is included in the category of small effects (0.02<F2<0.15), so it can be concluded that DF has a strong enough influence on the level of implementation of lean construction, However, it has little effect on time management.
2. The effect size (F2) of the extra processing variable of non-physic waste production (EP) on the implementation of lean construction (LC) of 0.008 was included in the category of very small effect (F2<0.02) and the effect size (F2) of the variable EP on time management (TM) of 0.012 was included in the category of small effect (0.02<F2<0.15), so it can be concluded that EP has a very weak influence on the level of implementation of lean construction and has a small effect on time management.
3. The effect size (F2) of the non-physic waste production (IV) inventory variable on the implementation of lean construction (LC) of 0.197 was included in the category of moderate effects (0.15<F2<0.35) and the effect size (F2) of the IV variable on time management (TM) of 0.289 was included in the category of moderate effects (0.15<F2<0.35), so it can be concluded that IV has a strong enough influence on the level of implementation of lean construction and time management.
4. The effect size (F2) of the implementation of lean construction (LC) of 0.073 is included in the category of small effects (0.02<F2<0.15), so it can be concluded that lean construction has a weak influence on time management.
5. The effect size (F2) of the non-physic waste production (MT) variable on the implementation of lean construction (LC) of 0.004 is included in the very small effect category (F2<0.02) and the effect size (F2) of the MT variable on time management (TM) of 0.016 is included in the medium effect category (0.15<F2<0.35), so it can be concluded that MT has a weak influence on the implementation rate of lean construction but has a fairly strong influence on time management.
6. The effect size (F2) of the non-utilization variable non physic waste production (NU) on the implementation of lean construction (LC) of 0.060 was included in the category of small effects (0.02<F2<0.15) and the effect size (F2) of the variable NU on time management (TM) of 0.035 was included in the category of medium effects (0.15<F2<0.35), so it can be concluded that NU has a weak influence on the level of implementation of lean construction and time management.
7. The effect size (F2) of the variable over production non physic waste production (OP) on the implementation of lean construction (LC) of 0.051 was included in the category of small effects (0.02<F2<0.15) and the effect size (F2) of the OP variable on time management (TM) of 0.029 was included in the category of small effects (0.02<F2<0.15), so it can be concluded that OP has a weak influence on the level of implementation of lean construction and time management.
8. The effect size (F2) of the transportation variable non physic waste production (TR) on the implementation of lean construction (LC) of 0.088 is included in the category of small effect (0.02<F2<0.15) and the effect size (F2) of the variable TR on time management (TM) of 0.047 is included in the category of large effect (0.35<F2), so it can be concluded that although TR has a weak influence on the implementation rate of lean construction, However, it has a strong influence on time management.
9. The effect size (F2) of the non-physic waste production (WT) waiting variable on the implementation of lean construction (LC) of 0.003 is included in the category of very small

effects (F2<0.02) and the effect size (F2) of the WT variable on time management (TM) of 0.041 is included in the category of medium effects (0.35<F2), so it can be concluded that although WT has a very weak influence on the implementation rate of lean construction, However, it has a strong influence on time management.

Statistical tests are a test of relationship significance in PLS-SEM to determine whether the relationship between latent variables in the model can be considered statistically significant. This process usually uses the bootstrapping technique, where the data is resampled to calculate the path coefficient and its standard errors. The results are reported in the form of t-statistical or p-value. A relationship is considered to have a very significant positive effect, if the p-value is smaller than the predetermined significance level (in this study a significance of 0.05) and a statistical T >1.645. Significant path coefficients indicate that the relationship between independent and latent dependent variables has strong statistical support, so the proposed hypothesis is acceptable. The following are the results of bootstrapping of direct effect and indirect effect research.

1. Direct effect bootstrapping results
   The results of the tests and analyses carried out in this study are then discussed to provide a more detailed picture of the influence and relationship between the variables used in the study.
   1. The effect of non-physical waste production defect indicators on lean construction.
      The results show that non-physical waste production defects have a very significant positive effect on lean construction with a coefficient (effect) value of 0.444, a T-statistic of 2.004 (>1.645), and a P-value of 0.023 (<0.05). This indicates that the better the quality management implemented, the higher the implementation of lean construction in the Pusri 3B project.
   2. The effect of non-physical waste production defect indicators on time management.
      The effect of non-physical waste production defects on time management shows insignificant results, because the T-statistic value of 0.700 is below the threshold (<1.645), and the P-value of 0.242 is above the threshold (>0.05). The coefficient of 0.084 indicates a positive relationship, meaning that the more non-physical waste production defects there are, the greater the potential for delays in completing the work.
   3. The effect of extra processing non-physical waste production indicators on lean construction.
      The effect of extra processing non-physical waste production on lean construction shows insignificant results, because the T-statistic value of 0.499 is below the threshold (<1.645), and the P-value of 0.309 is above the threshold (>0.05). The coefficient of 0.065 indicates a positive relationship, meaning that there is no extra processing of non-physical waste production that can affect the implementation of lean construction.
   4. The effect of extra processing of non-physical waste production on time management.
      The effect of extra processing non-physical waste production on time management shows insignificant results, because the T-statistic value is 0.357 below the threshold (<1.645), and the P-value is 0.361 above the threshold (>0.05). The coefficient of 0.051 indicates a positive relationship, meaning that there is no extra processing of non-physical waste production that can affect time management.
   5. The effect of non-physical waste production inventory indicators on lean construction.
      The results show that non-physical waste production inventory has a very significant positive effect on lean construction with a coefficient (effect) value of 0.587, a T statistic of 4.009 (>1.645), and a P value of 0.000 (<0.05). This indicates that the better the inventory management implemented, the higher the implementation of lean construction in the Pusri 3B project.
   6. The effect of non-physical waste production inventory indicators on time management.

The results show that non-physical waste production inventory has a very significant positive effect on time management with a coefficient value (effect) of 0.513, a T statistic of 2.712 (>1.645), and a P value of 0.003 (<0.05). This indicates that the better the inventory management applied, the better the control over time management.

7. The effect of lean construction indicators on time management.
   The results show that lean construction has a very significant positive effect on time management with a coefficient value (effect) of -0.225, which indicates a negative relationship, meaning that the less lean construction is implemented, with a T statistic of 1.974 (>1.645) and a P value of 0.024 (<0.05), causing an increase in the potential for delays in completing work.
8. The effect of motion non-physical waste production indicators on lean construction.
   The effect of non-physical waste production motion on lean construction shows insignificant results, because the T-statistic value of 0.479 is below the threshold (<1.645), and the P-value of 0.316 is above the threshold (>0.05). The coefficient of -0.092 indicates a negative relationship, meaning that as non-physical waste production motion increases, the implementation of lean construction decreases.
9. The effect of non-physical waste production motion indicators on time management.
   The effect of motion non-physical waste production on time management shows insignificant results, because the T-statistic value of 0.893 is below the threshold (<1.645), and the P-value of 0.186 is above the threshold (>0.05). The coefficient of 0.172 indicates a positive relationship, meaning that as non-physical waste production increases, the potential for delays in completing work also increases.
10. The effect of non-utilisation non-physical waste production indicators on lean construction.
    The effect of non-utilisation non-physical waste production on lean construction shows insignificant results, because the T-statistic value of 1.496 is below the threshold (<1.645), and the P-value of 0.067 is above the threshold (>0.05). The coefficient of 0.258 indicates a positive relationship, meaning that there is no non-utilisation non-physical waste production that can affect the implementation of lean construction.
11. The effect of non-utilisation non-physical waste production indicators on time management.
    The effect of non-utilisation non-physical waste production on time management shows insignificant results, because the T-statistic value of 0.707 is below the threshold (<1.645), and the P-value of 0.240 is above the threshold (>0.05). The coefficient of 0.109 indicates a positive relationship, meaning that the higher the non-utilisation of non-physical waste production, the greater the potential for delays in completing the work.
12. The effect of overproduction of non-physical waste production on lean construction.
    The effect of overproduction of non-physical waste production on lean construction shows very significant results, because the T-statistic value is 1.651 above the threshold (>1.645), and the P-value is 0.049 below the threshold (<0.05). The coefficient of 0.195 indicates a positive relationship, meaning that the lower the overproduction of non-physical waste, the better the effect on the implementation of lean construction.
13. The effect of the indicator of overproduction of non-physical waste on time management.
    The effect of non-physical waste production overproduction on time management shows insignificant results, because the T-statistic value of 1.597 is below the threshold (<1.645), and the P-value of 0.055 is above the threshold (>0.05). The coefficient of -0.169 indicates a negative relationship, meaning that the less non-utilisation of non-physical waste production, the better the control over time management.

14. The effect of the transportation non-physical waste production indicator on lean construction.
    The effect of non-physical waste production transportation on lean construction shows insignificant results, as the T-statistic value of 1.285 is below the threshold (<1.645), and the P-value of 0.099 is above the threshold (>0.05). The coefficient of -0.406 indicates a negative relationship, meaning that as transportation non-physical waste production decreases, the implementation of lean construction increases.
15. The effect of the transportation non-physical waste production indicator on time management.
    The effect of non-physical waste production transportation on time management shows insignificant results, because the T-statistic value of 1.630 is below the threshold (<1.645), and the P-value of 0.052 is above the threshold (>0.05). The coefficient of 0.349 indicates a positive relationship, meaning that with an increase in non-physical waste production, there is an increase in the potential for delays in completing work.
16. The effect of waiting non-physical waste production indicators on lean construction.
    The effect of waiting non-physical waste production on lean construction shows insignificant results, because the T-statistic value of 0.322 is below the threshold (<1.645), and the P-value of 0.374 is above the threshold (>0.05). The coefficient of -0.053 indicates a negative relationship, meaning that as waiting non-physical waste production decreases, the implementation of lean construction increases.
17. The effect of waiting non-physical waste production indicators on time management.
    The effect of waiting non-physical waste production on time management shows insignificant results, because the T-statistic value of 0.934 is below the threshold (<1.645), and the P-value of 0.175 is above the threshold (>0.05). The coefficient of -0.163 indicates a negative relationship, meaning that as waiting non-physical waste production decreases, time management control will improve.

2. Indirect effect bootstrapping results
   The results of the indirect effect bootstrapping can be seen in table 5.17 as follows:
   1. The effect of non-physical waste production defects on time management through lean construction.
      The analysis results show that non-physical waste production defects have an insignificant indirect effect on time management through lean construction, with a coefficient value of -0.100, a T statistic of 1.204 (<1.645), and a P value of 0.114 (>0.05). A negative coefficient value means that if the level of non-physical waste production increases, improvements in time management through lean construction tend to decrease. However, because this relationship is not significant, its interpretation cannot be used as a basis for strong decision making.
   2. The effect of extra processing non-physical waste production on time management through lean construction.
      The analysis results show that extra non-physical waste production has an insignificant indirect effect on time management through lean construction, with a coefficient value of -0.015, a T-statistic of 0.445 (<1.645), and a P-value of 0.328 (>0.05). A negative coefficient value means that if the level of extra processing of non-physical waste production increases, improvements in time management through lean construction tend to decrease. However, because this relationship is not significant, its interpretation cannot be used as a basis for strong decision making.
   3. The effect of inventory of non-physical waste production on time management through lean construction.
      The analysis results show that non-physical waste production inventory has a significant indirect effect on time management through lean construction, with a

coefficient value of -0.132, a T-statistic of 1.823 (>1.645), and a P-value of 0.034 (<0.05). A negative coefficient value means that if non-physical waste production inventory decreases, improvements in time management through lean construction tend to increase. As this relationship is significant, its interpretation can be used as a basis for strong decision making.

4. The effect of non-physical waste production motion on time management through lean construction.
   The analysis results show that non-physical waste production motion has an insignificant indirect effect on time management through lean construction, with a coefficient value of 0.021, a T-statistic of 0.429 (<1.645), and a P-value of 0.334 (>0.05). Although there is a positive direction of relationship with the coefficient value, the effect is so small that its impact on time management is almost imperceptible in practice.
5. The effect of non-utilisation non-physical waste production on time management through lean construction.
   The analysis results show that non-utilisation of non-physical waste production has an insignificant indirect effect on time management through lean construction, with a coefficient value of -0.058, a T-statistic of 1.067 (<1.645), and a P-value of 0.143 (>0.05). A negative coefficient value means that if the level of non-utilisation of non-physical waste production increases, improvements in time management through lean construction tend to decrease. However, because this relationship is not significant, its interpretation cannot be used as a basis for strong decision making.
6. The effect of overproduction of non-physical waste production on time management through lean construction.
   The analysis results show that overproduction of non-physical waste production has an insignificant indirect effect on time management through lean construction, with a coefficient value of -0.044, a T-statistic of 1.247 (<1.645), and a P-value of 0.106 (>0.05). A negative coefficient value means that if the level of non-physical waste production increases, improvements in time management through lean construction tend to decrease. However, because this relationship is not significant, its interpretation cannot be used as a basis for strong decision making.
7. The effect of non-physical waste transportation on time management through lean construction.
   The analysis results show that non-physical waste production in transportation has an insignificant indirect effect on time management through lean construction, with a coefficient value of 0.091, a T-statistic of 0.936 (<1.645), and a P-value of 0.175 (>0.05). Although there is a positive direction of relationship with the coefficient value, the effect is so small that its impact on time management is almost imperceptible in practice.
8. The effect of waiting non-physical waste production on time management through lean construction.
   The analysis results show that waiting non-physical waste production has an insignificant indirect effect on time management through lean construction, with a coefficient value of 0.012, a T-statistic of 0.262 (<1.645), and a P-value of 0.397 (>0.05). Although there is a positive directional relationship with the coefficient value, the effect is very small, so that its influence on time management is almost imperceptible in practice..

CONCLUSION

This study demonstrated that in the PUSRI 3B EPC project, specific Lean Six Sigma non-physical wastes—particularly inventory—significantly influenced project time management, with Lean Construction serving as a crucial mediator. Inventory waste directly affected both Lean Construction implementation and time management, while defect and overproduction wastes impacted Lean Construction but not delays due to quality controls; other wastes (waiting, transportation, motion, extra processing, non-utilization) showed no significant direct effects. Lean Construction implementation itself significantly enhanced time management, confirming its role in mitigating key wastes like inventory. For future research, validate these findings across diverse project types, scales, and contexts through longitudinal studies tracking waste, Lean adoption, and performance over full lifecycles, complemented by mixed-methods (e.g., surveys plus interviews) to uncover managerial and behavioral drivers of waste criticality for targeted strategies.

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