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Enhancing Brick Production Efficiency through the Implementation of Lean Manufacturing using the Waste Assessment Model (WAM)

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ABSTRACT

Competition in the manufacturing sector requires companies of all sizes to maintain efficient production performance and eliminate waste. Lean Manufacturing serves as a strategic approach to minimize waste and enhance process efficiency. UD Surya, a small-scale enterprise producing concrete bricks, faces various challenges related to production capacity and effectiveness, particularly involving wastes such as overproduction, defects, inventory, processing, waiting, transportation, and motion. This study aims to improve the efficiency of brick production through the implementation of Lean Manufacturing using the Waste Assessment Model (WAM). The WAM method is employed to quantitatively identify waste levels, supported by Pareto diagram analysis to determine priority issues. The results indicate that several categories of waste exceed the 15% threshold, requiring immediate corrective actions to prevent further losses and improve production efficiency. These findings demonstrate that the application of Lean Manufacturing based on WAM is effective in identifying critical waste and provides a strong foundation for continuous improvement strategies in the brick production process at UD Surya.

Keywords: Brick, Lean Manufacturing, Waste Assessment Model (WAM), Production Efficiency.

1. INTRODUCTION

The sustainability and competitiveness of the manufacturing industry are heavily influenced by a company's ability to maintain operational stability and implement continuous improvement in its production processes. Changing consumer demand, product variety, market dynamics, and economic uncertainty require companies to develop adaptive and efficient production systems. Lean Manufacturing has emerged as a strategic approach aimed at increasing value-added activities by eliminating non-value-added activities, commonly referred to as waste. Lean Manufacturing emphasizes the reduction and elimination of seven types of waste: overproduction, defects, inventory, improper processes, waiting time, transportation, and motion [1], [2]. Numerous studies have shown that these seven types of waste are dominant factors contributing to low production efficiency. [2] highlight that process, transportation, and motion waste are consistently the largest contributors to inefficiency in small and medium-sized manufacturing industries. For example, overproduction occurs when output exceeds actual demand; defects arise from errors or quality inconsistencies; excessive inventory leads to wasted space and storage costs; improper processes result from suboptimal procedures; waiting time arises from idle time that does not add value; and transportation and motion are related to inefficient movements and layouts [3]. Eliminating these various types of waste is crucial not only for improving operational efficiency but also for improving quality and reducing production costs.

Implementing Lean Manufacturing requires an analytical approach capable of quantitatively measuring waste levels and determining improvement priorities. The Waste Assessment Model (WAM) is an effective waste evaluation method and has been widely applied in modern Lean research [4]. Developed in [5], this model provides a comprehensive assessment of the severity of each type of waste and identifies improvement priorities based on the resulting scores [6], [7]. The study presented in [7] demonstrated that WAM can accurately represent the proportion of waste and is highly useful for formulating waste elimination strategies in small industries and labor-intensive sectors. Visualizing evaluation results using a Pareto diagram further simplifies the identification of dominant waste that requires immediate improvement.

UD Surya, a small-scale concrete block manufacturer, faces several significant waste-related issues. These issues include inaccuracies in raw material procurement planning, excess production capacity that does not match demand, material inventory buildup, and variations in worker skills that impact product quality. Additional waste is found in process areas, such as improper material storage, unused raw material waste like cement, and workflow designs that lead to excessive transportation and movement. These findings align with a study by [8] which showed that small-scale industries in the building materials sector are highly vulnerable to process and transportation waste due to irregular production flows and a lack of standardization. This study was developed based on the urgent need to improve production efficiency in the concrete block production process at UD Surya. The main objective of this study is to apply Lean Manufacturing using the WAM approach to identify waste levels, determine dominant waste priorities, and formulate appropriate improvement recommendations. The findings of this study are expected to provide academic contributions to the development of Lean research in small-scale industries while providing practical benefits to improve the effectiveness and sustainability of the concrete block production process.

2. METHODS

This research was designed using a descriptive-quantitative approach with structured and periodic research stages to identify, analyze, and evaluate waste in the concrete block production process at UD Surya. The research process consists of several main steps as follows:

1.1. Identification of Problems

The initial stage involves direct observation of the concrete block production process to identify the types and forms of waste occurring. This initial observation serves as the basis for determining the focus of the analysis regarding inefficiencies in the production process.

1.2. Formulation of The Problem

The results of the initial identification are used to formulate a clear problem statement, particularly regarding the categories of waste that occur, the severity of the waste, and its impact on the effectiveness of the production process.

1.3. Implementation of Research Objectives

The research objectives are formulated based on the established problem formulation, namely analyzing the level of waste and determining corrective actions through the application of Lean Manufacturing with the WAM approach.

1.4. Literature Study

The literature review was conducted by examining previous research related to:

a. the concept of Lean Manufacturing,
b. seven types of waste,
c. the application of WAM, and
d. the use of Pareto charts to prioritize problems.

This literature review aims to ensure the suitability of the analytical method to the characteristics of the research being conducted, while also strengthening the theoretical foundation.

1.5. Data Collection

Data collection was conducted using a primary data approach through:

a. Direct observation of production flow, layout, raw material usage, and worker activities.
b. Structured interviews with production owners, supervisors, and operators to obtain in-depth information regarding the causes of waste.

The data collection instrument refers to the waste indicators in WAM as shown in Table 1.

1.6. Analysis Using WAM

The collected data was analyzed using the WAM method through the following steps:

a. assigning a score to each waste category,
b. calculating the severity level of each waste,
c. determining priorities based on the highest scores.

This approach was used to provide a quantitative overview of waste levels at UD Surya.

1.7. Analysis Pareto Diagram

The WAM score results are visualized using a Pareto chart to show the percentage contribution of each type of waste. This visualization facilitates the identification of dominant waste that requires immediate attention for process improvement.

Table 1. Question *Seven Waste Relationship* (SWR).

No	Question	Answer Choices	Weight
1	Does i cause or produce j?	a.Ayways	4
		b.Sometimes	2
		c.Rerely	0
2	What is the relationship between i and j?	a.If i goes up, then j also goes up	2
		b.If i increases, then j remains the same	1
		c.Not necessarily, it depends on the circumstances	0
3	Impact j due to i?	a. Appears directly and clearly	4
		b. It takes time to be seen	2
		c. Not visible	0
4	Eliminating the effect of i on j can be achieved by?	a. Engineering methods	2
		b. Simple and direct	1
		c. Instructional solutions	0
5	Impact j caused by i affects?	a. Product quality	0
		b. Resource productivity	1
		c.Lead time	1
		d. Quality in Productivity	1
		e. Quality in lead time	2
		f. Productivity in lead time	2
		g. Quality, Produktivity and lead time	4
6	How much will i impact j to increase lead time?	a. Very high	4
		b. Currently	2
		c. Low	0

The questionnaire instrument presented in the table serves as a structured assessment tool completed by experts. Each question is designed to identify the incidence, severity, and interrelationships among different types of waste in a production system. The instrument contains 31 waste indicators classified into seven waste categories overproduction, defects, inventory, process, lead time, transportation, and movement—based on the definitions proposed in [2]. The use of these 31 indicators enables a comprehensive diagnostic analysis, systematically identifying all forms of non-value-added activities at every stage of the production process [9]. Expert responses serve as the primary qualitative data in the Waste Assessment Model (WAM), which is then used to calculate waste scores, map relationships between wastes, and prioritize corrective actions. This structured approach increases methodological rigor through: (1) alignment with existing waste taxonomies, (2) a replicable expert-based evaluation process, and (3) support for further quantitative analysis within a Lean Manufacturing framework.

Table 2. Types of relationships on (SWR).

The type of relationship between i and j			
O-I	D-O	M-W	I-T
O-D	D-I	T-O	P-D
O-M	D-M	T-I	P-M
O-T	D-T	T-D	P-W
O-W	D-W	T-M	W-O
I-O	M-I	T-W	W-I
I-D	M-D	P-O	W-D
I-M	M-P	P-I	W-M

Table 2 presents the relationships between waste types used in the Waste Assessment Model (WAM), where the i and j indices in the SWR matrix are replaced with waste symbols as defined by [10]. Each waste type is coded: O for Overproduction, I for Inventory, D for Defect, T for Transportation, M for Motion, and W for Waiting. The use of these symbols aims to simplify the construction of the waste relationship matrix and ensure consistency in data processing. To collect the quantitative data required for the WAM analysis, this study used the Waste Assessment Questionnaire (WAQ), a structured instrument containing questions related to the level of interrelationship between wastes based on actual conditions in the production line. [11] The questions in the WAQ are formulated to reveal the influence of human, material, machine, method, and environmental factors on the occurrence of waste. Each response is scored using a three-level scoring scheme: A is worth 1 (high relationship), B is worth 0.5 (moderate relationship), and C is worth 0 (no significant relationship). These scores are then directly used to populate the elements of the SWR matrix.

The WAQ was completed by experts with a deep understanding of the concrete block production process at UD Surya, including business owners, foremen, and experienced operators, ensuring that the collected data reflected actual conditions. Prior to formal data collection, the instrument was piloted to ensure question clarity. Interviews and field observations were conducted to validate responses, reduce subjectivity, and ensure consistency of assessments among experts [12]. Responses were then processed to create an SWR matrix, where each element reflects the magnitude of the relationship between waste types based on the WAQ score. These values were summed to produce a severity rating for each waste category. Normalization was performed so that waste values could be expressed as a percentage, which was then compared to a 15% threshold to determine which waste categories required priority improvement.

The WAM calculation results were then analyzed using a Pareto diagram to identify the waste categories that most contribute to production inefficiencies. The Pareto visualization made it easier for researchers to identify critical waste, which accounts for approximately 80% of total waste, thus becoming the primary focus for developing improvement recommendations. This approach provides a strong foundation for developing more targeted lean strategies, both in the form of short-term improvements and continuous improvement programs in the concrete block production process.

Table 3. Examples of FAQ questions on brick Production.

No	Aspects and questions	Answer	Information	Score WAQ
Man				
1.	Does the management frequently transfer operators for all jobs so that one type of job can be done by all operators?	A	To Motion	1
2.	Have workers often received training in mixing and molding the brick making process?	C	From Motion	0
Material				
12.	Are materials moved more often than needed?	B	To Defect	0,5
Transportation				
31.	Do finished or finished bricks have to be moved to another place?	C	To Transportation	0

The Waste Assessment Questionnaire (WAQ) was used to identify seven types of waste in the concrete block production process. Instrument development began with identifying question constructs that addressed seven categories of waste: overproduction, inventory, defects, movement, transportation, waiting, and overprocessing [13]. Each construct was formulated based on an analysis of the concrete block production workflow, which includes material preparation, mixing, molding, drying, and final storage. Based on this analysis, a 68-item WAQ was developed to represent all process stages and comprehensively map potential waste. The instrument then underwent content validation by Lean Manufacturing experts and readability testing with production operators to ensure relevance, clarity, and appropriateness to the operational context. Once the instrument was deemed valid, respondents completed all 68 items and assigned a waste level score for each associated activity.

The collected data was then processed through several stages of analysis. The first stage involved summing the WAQ scores for each questionnaire item to obtain an initial overview of the level of waste in the production process. Next, the Waste Severity Level (WSL) was calculated to determine the severity of each type of waste. This process was followed by score normalization to ensure that each waste category had a comparable weighting scale, allowing for a more objective analysis of its contribution to the production system.

The next step was to develop a Waste Relationship Matrix (WRM), an analytical tool for identifying and evaluating relationships between waste types. Relationships between wastes were determined based on Lean literature and observations of production processes, and classified into four levels of influence: X (critical), A (very strong), E (strong), and O (weak). The WRM matrix was then constructed by placing seven types of waste on the horizontal and vertical axes, and each relationship was filled in according to its level of interconnectedness. To enable quantitative analysis, each relationship symbol was converted to a numeric value (X = 9, A = 3, E = 1, and O = 0). The initial weight of each waste was calculated by summing all relationship values in the corresponding WRM row, thus obtaining an overview of the level of influence (strength of influence) of each waste on the others. The waste with the highest initial weight was designated as the critical waste, that is, the type of waste that has the greatest contribution to the inefficiency of the production system and should be prioritized in the Lean improvement strategy.

Through the WAQ and WRM stages, this study produced two main outputs: a waste profile based on 68 WAQ items and a critical waste hierarchy, which serve as a basis for formulating improvement actions and priority strategies in implementing Lean in the concrete block production process.

Table 4. Example WRM.

Question Type	Question (K)	O	I	D	M	T	P	W
Classification (1): Man								
To Motion	1	10	8	4	0	4	4	4
From Motion	2	8	10	6	6	4	4	4
From Defect	3	2	8	10	8	4	4	4
From Motion	4	8	8	6	10	4	4	0
From Motion	5	8	8	0	0	10	4	0
From Defect	6	0	0	6	6	0	10	0
From Process	8	0	0	6	6	0	10	0

Based on Table 3, the eight sample questions used in the Human aspect are part of the overall waste identification instrument. Each question is evaluated using seven waste categories, namely Overproduction (O), Inventory (I), Defects (D), Motion (M), Transportation (T), Overprocessing (P), and Waiting (W). The score for each category is obtained from the waste relationship matrix developed in the previous stage, which ensures that each question item reflects its level of relationship with each type of waste. In addition to the Human aspect, this instrument also covers the Material, Machine, and Method aspects, resulting in a total of 68 questions representing all key elements in the production process. The next step is to calculate the Initial Score (Sj awal) and Initial Frequency (Fj awal) for each waste category. The initial score is calculated based on the accumulated value of the waste relationship for each questionnaire item, while the initial frequency is obtained from the number of occurrences or tendencies of waste identified through questionnaire responses. Once these initial values are obtained, the analysis continues by calculating the Final Score (Sj akhir) and Final Frequency (Fj akhir) through normalization and weight adjustment, thus producing a more proportional representation of the severity and dominance of each type of waste in the production system.

Final scores and frequency calculations are used to determine the priority level of each waste type based on its percentage contribution to the overall waste occurring in the production process. Waste categories are then ranked from highest to lowest percentage to identify the most dominant and detrimental waste types. Waste exceeding 15% is categorized as critical and deemed to require immediate corrective action. Establishing a 15% threshold provides an objective basis for better decision-making, while ensuring that Lean development resources are focused on areas with the greatest impact on improving production process efficiency.

1.8. Research Framework

This research framework is designed to provide a clear and structured analytical flow in identifying and evaluating waste in the concrete block production process at UD Surya. This framework integrates Lean Manufacturing concepts through the Waste Assessment Model (WAM), the Waste Assessment Questionnaire (WAQ), and the Waste Relationship Matrix (WRM), so that all stages from problem identification, data collection, quantitative analysis, to the preparation of recommendations are carried out systematically and consistently. The research framework used is shown in Figure 1, which illustrates the logical relationship between stages and the analytical process flow in this study.

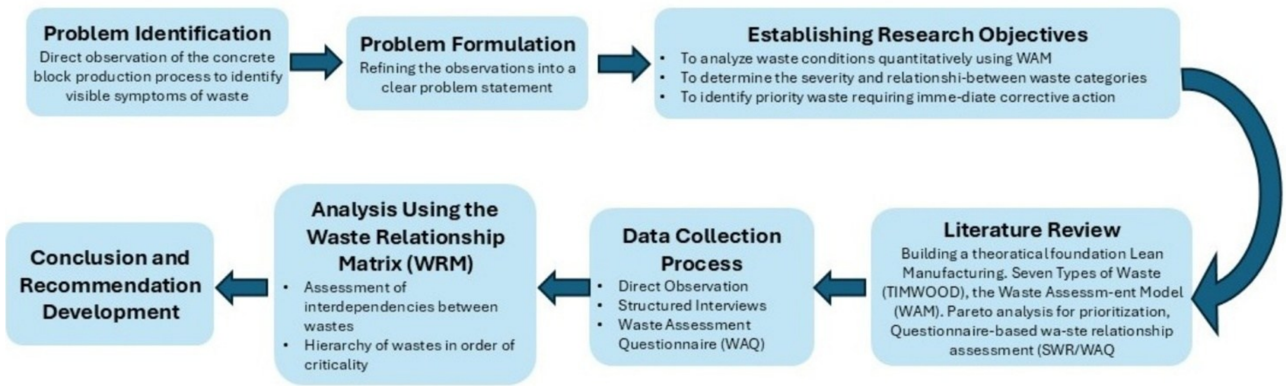

Figure 1. Research Framework

3. RESULT AND DISCUSSION

3.1. SWR Analysis

Based on the results of data processing using the Seven Waste Relationship instrument, a general overview of the relationship between types of waste in the concrete block production process at UD Surya was obtained. The analysis was conducted by referring to the waste relationship values summarized for each questionnaire item. The results of the calculation of the relationship between waste categories covering the aspects of Human, Material, Machine, and Method are then summarized in Table 5, which presents the relative influence values between types of waste and their level of dominance in the production system.

Table 5. Results SWR

No	Types Of Relationships	Total Score	Symbol
1	O-I	18	A
2	O-D	3	U
3	O-M	6	O
4	O-T	16	E
5	O-W	10	I
6	I-O	4	U
7	I-D	18	A

No	Types Of Relationships	Total Score	Symbol
8	I-M	20	A
9	I-T	18	A
10	D-O	8	O
11	D-I	20	A
12	D-M	10	I
13	D-T	10	I
14	D-W	14	E
15	M-I	17	A
16	M-D	14	E
17	M-W	10	I
18	M-P	18	A
19	T-O	3	U
20	T-I	14	E
21	T-D	14	E
22	T-M	17	A
23	T-W	16	E
24	P-O	12	I
25	P-I	8	O
26	P-D	16	E
27	P-M	14	E
28	P-W	16	E
29	W-O	7	O
30	W-I	10	I
31	W-D	6	O

Based on Table 5, the total score for each type of waste is obtained by summing the scores from the six questions formulated according to the relationships between wastes in the Seven Waste Relationship matrix. This total provides a quantitative representation of the level of contribution of each waste to the overall inefficiency of the production process. To facilitate interpretation of the severity of waste, the numerical scores are then classified into letter symbol categories based on a rating scale developed by Rawahdeh (2005). The scale consists of six categories: A for a value ≥ 17, E for a value ≥ 13, I for a value ≥ 9, O for a value ≥ 5, U for a value ≥ 1, and X for a value = 0. This classification is used to indicate the level of strength of the waste relationship, ranging from very strong (A) to no relationship (X). Through this approach, the analysis results in Table 5 can be presented in a more structured manner and provide a clearer understanding of the level of dominance and interrelationships between wastes in the concrete block production process.

3.2. WRM Analysis

Table 6 presents the process of transferring the Seven Waste Relationship (SWR) values into a relationship matrix as the initial stage of quantitative analysis between waste categories. This process begins by mapping all letter symbols obtained from the SWR classification into the appropriate cells of the relationship matrix based on the position of the interactions between the wastes. After all qualitative relationships are entered into the matrix, the letter symbols are converted into numerical values using a predetermined weighting scheme, namely A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0. This weighting aims to produce a quantitative representation of the strength of the relationships between wastes so that they can be analyzed more objectively.

Table 6. WRM

F/T	O	I	D	M	T	P	W
O	A	A	U	O	E	X	I
I	U	A	A	A	A	X	X
D	O	A	A	I	I	X	E
M	X	A	E	A	X	I	A
T	U	E	E	A	A	X	E
P	I	O	E	E	X	A	E
W	O	I	O	X	X	X	A

The results of this conversion are then presented in Table 7, which is a quantitative form of the Waste Relationship Matrix (WRM). This table displays the numerical values obtained from the transformation of the letter symbols in Table 6, thus providing a comprehensive picture of the intensity of the relationship between various types of waste in the brick production process. Thus, Table 7 serves as a basis for further analysis, including the calculation of influence scores, determining the relative contribution of each type of waste, and identifying critical waste that requires prioritization for improvement efforts.

Table 7. Results of WRM values

F/T	*O*	*I*	*D*	*M*	*T*	*P*	*W*	*Skor*	*%*
O	10	10	2	4	8	0	6	**40**	**14,08**
I	2	10	10	10	10	0	0	**42**	**14,79**
D	4	10	10	6	6	0	8	**44**	**15,49**
M	0	10	8	10	0	6	10	**44**	**15,49**
T	2	8	8	10	10	0	8	**46**	**16,20**
P	6	4	8	8	0	10	8	**44**	**15,49**
W	4	6	4	0	0	0	10	**24**	**8,45**
Skor	**28**	**58**	**50**	**48**	**34**	**16**	**50**	**284**	**100,00**
%	**9,86**	**20,42**	**17,61**	**16,90**	**11,97**	**5,63**	**17,61**	**100,0**	

3.3. Dominant Waste (Identify the Largest Contribution to Waste)

Based on the total percentage value obtained from the matrix relationship calculation, the waste with the largest contribution was identified in the To Inventory category at 20.42%, followed by From Transportation at 16.20%. These two types of waste show a high level of influence in the brick production chain, indicating their potential as dominant factors that reduce the overall process efficiency. These percentages are obtained through the analysis of influence scores calculated from the inter-waste relationship matrix, thus providing a comprehensive picture of the direction and magnitude of the impact of each waste on the production system. After completing the calculation of the waste level using the Waste Relationship Matrix (WRM), the next step is to group the data based on the converted matrix relationships presented in Table 7. This grouping aims to periodically rearrange the relationships between wastes, thus facilitating the identification of relationship patterns and the direction of influence between waste categories. Next, these relationships are arranged into a grouped relationship matrix, as shown in Table 8. This table presents the structure of the WRM that has been classified based on the dominant relationships between waste types, which serves as a basis for prioritizing improvement actions and determining critical waste in the brick production process.

Table 8. Grouping WRM data into Matrix relationships

Question Number	Question Type	O	I	D	M	T	P	W
Classification (1): Man								
1	To motion	4	10	6	10	10	6	0
2	From motion	0	10	8	10	0	6	10
3	From defects	4	10	10	6	6	0	8
4	From motion	0	10	8	10	0	6	10
5	From motion	0	10	8	10	0	6	10
6	From defects	4	10	10	6	6	0	8
7	From process	4	10	10	6	6	0	8
Classification (2): Material								
8	To waiting	6	0	8	10	8	8	10
9	From waiting	6	0	8	10	8	8	10
10	From transportation	2	8	8	10	10	0	8
11	From inventory	2	10	10	10	10	0	0
12	From inventory	2	10	10	10	10	0	0
13	From defects	4	10	10	6	6	0	8
14	From inventory	2	10	10	10	10	0	0
15	From waiting	6	0	8	10	8	8	10
16	To defects	2	10	10	8	8	10	8
17	From defects	4	10	10	6	6	0	8
18	From transportation	2	8	8	10	10	0	8
19	To motion	4	10	6	10	10	6	0
20	From waiting	4	6	4	0	0	0	10
21	From motion	0	10	8	10	0	6	10
22	From motion	0	10	8	10	0	6	10
23	From defects	4	10	10	6	6	0	8
24	From motion	0	10	8	10	0	6	10
25	From inventory	2	10	10	10	10	0	0
26	From inventory	2	10	10	10	10	0	0
27	To waiting	6	0	8	10	8	8	10
28	From defects	4	10	10	6	6	0	8
29	From waiting	4	6	4	0	0	0	10
30	From overproduction	10	10	2	4	8	0	6
31	To motion	4	10	6	10	10	6	0
Classification (1): Machine								

Question Number	Question Type	O	I	D	M	T	P	W
32	From process	4	10	10	6	6	0	8
33	To waiting	6	0	8	10	8	8	10
34	From process	4	10	10	6	6	0	8
35	From transportation	2	8	8	10	10	0	8
36	To motion	4	10	6	10	10	6	0
37	From overproduction	10	10	2	4	8	0	6
38	From waiting	4	6	4	0	0	0	10
39	From waiting	4	6	4	0	0	0	10
40	To defects	2	10	10	8	8	10	8
41	From waiting	4	6	4	0	0	0	10
42	To motion	10	6	2	4	8	0	6
43	From process	4	10	10	6	6	0	8
Classification (4): Method								
44	To transportation	8	10	6	0	10	6	0
45	From motion	0	10	8	10	0	6	10
46	From waiting	4	6	4	0	0	0	10
47	To motion	4	10	6	10	10	6	0
48	From defects	4	10	10	6	6	0	8
49	To defects	2	10	10	8	8	10	8
50	From motion	0	10	8	10	0	6	10
51	From defects	4	10	10	6	6	0	8
52	From motion	0	10	8	10	0	6	10
53	To waiting	6	0	8	10	8	8	10
54	From process	4	10	10	6	6	0	8
55	From process	4	10	10	6	6	0	8
56	To defects	2	10	10	8	8	10	8
57	From inventory	2	10	10	10	10	0	0
58	To transportation	8	10	6	0	10	6	0
59	To motion	4	10	6	10	10	6	0
60	To transportation	8	10	6	0	10	6	0
61	To motion	4	10	6	10	10	6	0
62	To motion	4	10	6	10	10	6	0
63	From motion	0	10	8	10	0	6	10
64	From motion	0	10	8	10	0	6	10
65	From motion	0	10	8	10	0	6	10
66	From overproduction	10	10	2	4	8	0	6
67	From process	4	10	10	6	6	0	8
68	From defects	4	10	10	6	6	0	8

3.4. Calculation of Sj & Fj (Initial and Final Scores and Frequencies)

The Analysis of the Relationships of Seven Wastes at UD. Surya provides a comprehensive overview of the interrelationships between various types of waste in the brick production process. The initial identification of the seven waste categories is systematically processed and presented in Table 5, which serves as a basis for understanding the cause-and-effect relationships between various sources of operational inefficiency. Each type of waste is evaluated based on its level of influence on other wastes, resulting in a comprehensive relational map of the interactions between wastes.

Next, the inter-waste relationships initially represented using letter-based classifications in the relationship matrix were converted into numerical values based on the WRM. This transformation is presented in Table 7, which assigns quantitative weights to each pair of wastes. This conversion allows for more objective interpretation, facilitates the weighting process, and strengthens the validity of the overall analysis. Thus, the integration of Tables 5 and 7 not only clarifies the structure of inter-waste relationships but also provides a solid foundation for informed decision-making in implementing continuous improvement efforts at UD. Solar.

Sj initial = $\sum_{E=1}^{E} \frac{Wj.k}{Ni}$ whereas Fj initial = many factorial values (Wo.k) ≥ 1.

Score Initial (Sj Initial)		47,4	94,8	81,1	73,0	73,7	37,9	69,1
Frequency Initial (Fj Initial)		56	62	68	59	50	33	51

Figure 2. Initial Sj and Initial Fj Results

Based on Figure 2, the results of the Initial Score (Sj awal) and Initial Frequency (Fj awal) calculations are presented, which reflect the intensity and prevalence of each type of waste in the brick production process. These initial values are derived from the aggregate relationship weights in the WRM, which are mapped to items in the WAQ instrument, thus providing an initial picture of waste patterns before respondent-based adjustments.

The next step in the analysis is to obtain the Final Score (Sj final) and Final Frequency (Fj final), which reflect the waste status after the weighted questionnaire responses are combined. This process begins by calculating intermediate values for each cell in the relationship matrix (i.e., the initial values of each waste pair calibrated with the scoring factors obtained from the questionnaire), resulting in adjusted values that take into account practical preferences and field experience. These intermediate values are then aggregated for each waste category and transformed into two final indicators: Sj final, which represents the adjusted average influence intensity, and Fj final, which represents the relative frequency of waste occurrence based on WAQ responses. The final results are compiled into a summary table for easy interpretation and comparison (see Table 9 for a summary of Sj final and Fj final).

To ensure the accuracy of the interpretation, validation steps were also performed: checking the consistency of the mapping from question items to waste categories, testing the internal reliability of the instrument (to ensure the homogeneity of items within each waste group), and conducting a sensitivity analysis related to variations in the questionnaire weighting. The final Sj and Fj outputs were then used to calculate the percentage contribution of each waste to the total waste; wastes that showed significant contributions were identified as priorities for improvement. All initial (Figure 1) and final (Table 9) values are presented side by side so that the reader can observe changes in the assessments after calibration with empirical data, and evaluate the consistency and reliability of the analysis results.

$$\text{Sj final} = \sum_{E=1}^{E} X_K \frac{Wj.k}{Ni} \text{ whereas Fj final = many factorial values (Wo.k)} \geq 1.$$

Score Final (Sj Final)			24,3	49,5	41,9	38,8	36,7	18,4	38,7
Frequency (Fj Final)			41	46	50	43	36	23	39

Figure 3. Final Sj and Final Fj results

Based on Figure 3, the Final Score (Sj final) and Final Frequency (Fj final) values were obtained for all waste categories in the brick-making process. These final scores are the result of adjusting the initial scores after incorporating the respondents' weighted assessments, thus providing a more accurate picture of the actual severity and frequency of each waste type.

3.5. Waste Probability

After obtaining a complete set of initial scores, final scores, initial frequencies, and final frequencies, the next step is to calculate the probability values for each type of waste. This calculation is performed by integrating the intensity and impact factors of the waste, resulting in a composite measure that reflects the relative likelihood of each type of waste occurring in the production process.

The results of the probability calculations are then presented comprehensively in Table 9, which displays the probability contribution of each waste type to the total waste. This table identifies the waste categories with the highest probability, indicating which waste has the potential to have the most significant impact on production process efficiency.

This probabilistic approach allows for objective prioritization of improvements, considering not only the magnitude of each waste's impact but also its frequency. Thus, the analysis presented in Table 9 provides a strong foundation for formulating a targeted, data-driven improvement strategy for UD. Solar's concrete block production process.

Tabel 9. Probability Value

Percentage	O	I	D	M	T	P	W
Row	14,08	14,79	15,49	15,49	16,20	15,49	8,45
Column	9,86	20,42	17,61	16,90	11,97	5,63	17,61
Pj	1,43	0,72	0,88	0,92	1,35	2,75	0,48

Based on Table 9, the row and column values are derived from the percentages of inter-waste relationships previously calculated in Table 7 (WRM). The row values represent the accumulated percentage of inbound influence received by each waste category, while the column values reflect the percentage of outbound influence provided by each waste. The combination of these two values provides a comprehensive picture of the role of each waste in the overall structure of inefficiencies in the concrete block production process—indicating whether certain wastes act more as drivers or recipients of influence from other waste types.

3.6. Final Waste Value & Pareto Analysis

After calculating the probability values for each waste category, the final analysis step is to determine the final waste value for each type of waste. This final waste value is obtained by integrating probability information with waste severity and frequency, resulting in a more representative measure for prioritizing waste mitigation in the production process. The final integration results are comprehensively presented in Table 10, which displays waste values for all waste categories. This table serves as the primary basis for determining priority areas for improvement, as the waste categories with the highest final waste values contribute the most to inefficiencies in the brick production process at UD. Surya. Thus, the analysis presented in Table 10 provides a comprehensive understanding of the waste hierarchy and serves as a strategic foundation for formulating a Lean-based improvement plan in the brick manufacturing industry.

Table 10. Final waste calculation results

Description/Waste	O	I	D	M	T	P	W
Pj	1,43	0,72	0,88	0,92	1,35	2,75	0,48
Yj Initial	0,50	1,65	1,00	1,12	1,50	0,92	1,34
Yj Final	0,72	1,19	0,88	1,02	2,03	2,53	0,64
WP	7,96	13,22	9,74	11,34	22,55	28,02	7,15
Rank	6	3	5	4	2	1	7

Based on the results of the final waste calculation in the brick production process, it can be identified that the waste category with the largest contribution is Process (P), with a value of 28.02%, which indicates that the most inefficiencies occur in stages or work methods that do not provide added value. The second highest contribution is Transportation (T), with a value of 22.55%, which indicates the existence of inefficient and repetitive material movements during the production process. Other waste categories follow in sequence, with the smallest contribution being Waiting (W), with a value of 7.15%, which indicates that idle time has a relatively lower impact compared to other types of waste. To provide a clearer visualization of waste distribution, a Pareto Diagram was created to illustrate the relative dominance of each waste to the total waste in the concrete block production process. This diagram facilitates the identification of waste that is a top priority for improvement, as categories located on the left side of the curve particularly Process and Transportation show the greatest contribution to overall inefficiency and therefore require immediate corrective action within the framework of Lean Manufacturing implementation.

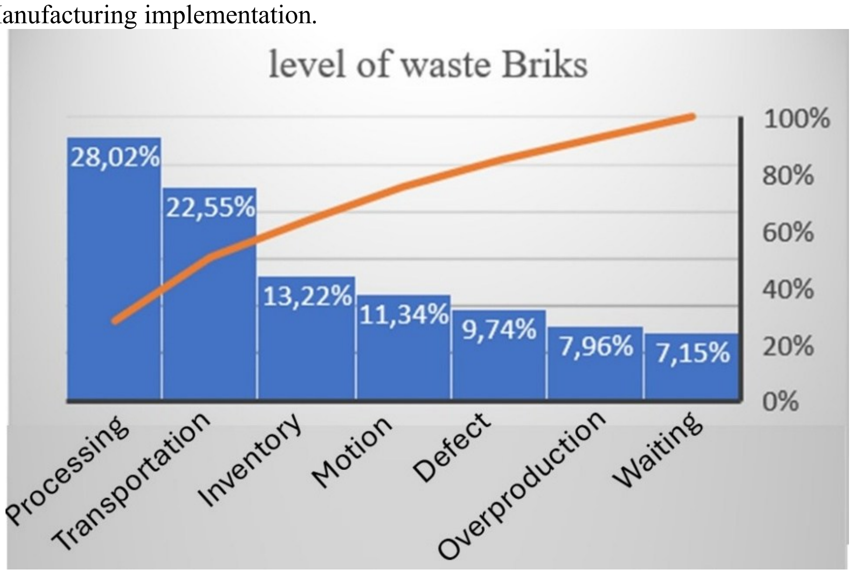

Figure 4. Pareto Diagram of Waste

4. CONCLUSION

Based on waste analysis of the brick production process at UD. Surya, two categories of waste were identified that exceeded the critical threshold of 15%: Process and Transportation. These two types of waste contribute significantly to overall production inefficiency and therefore require prioritization and immediate corrective action. In the Process category, the main sources of waste are related to inconsistent material ratios and sizes, as well as the use of less than uniform manual work methods. Therefore, improvements can be made by standardizing material mixing ratios, standardizing mold sizes, and implementing hydraulic presses to replace manual molding processes. Implementing these improvements is expected to improve product quality stability, speed up the production process, and reduce variability in the final product.

Meanwhile, in the Transportation category, waste arises from inefficient production layouts, which force workers to repeatedly move materials and equipment unnecessarily. Improvements can be made by rearranging the placement of raw materials, equipment, and printing areas to be closer and more integrated. This reorganization not only reduces non-value-added movement but also reduces worker fatigue and improves production flow. Overall, implementing improvement measures for these two waste categories has the potential to significantly increase productivity, time efficiency, and product quality. Therefore, these improvement recommendations form a strategic basis for UD. Surya in developing a leaner, more effective, and more sustainable production system.

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