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Analysis of Lean Manufacturing Using the Waste Assessment Model (WAM) to Reduce Waste in the Bolt Production Process at PT.XYZ

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Abstract. PT.XYZ was established in 1975 and is a manufacturer of bolts, nuts, anchor bolts, stud bolts, tapping screws, and washers in Southeast Asia, with an annual production capacity of 48,000 tons. These products serve various industries such as construction, manufacturing, automotive, and general industries. Despite careful planning, challenges in large production volumes and varied product specifications remain obstacles in meeting customer demand. Amidst global competition and stringent industry standards, implementing lean manufacturing is crucial to enhance efficiency and competitiveness. This study aims to identify waste ≤ 17% using the Waste Assessment Model, conduct Root Cause Analysis to pinpoint waste origins, and propose improvement strategies using 5W+1H Analysis. Findings reveal Inventory (21.44%) as the highest waste contributor, attributed to interdepartmental coordination issues, production errors, lack of operator focus, delayed resource availability, and production flow bottlenecks. Additionally, Defects (18.47%) arise from excessive workload on production operators. Improvement recommendations include enhancing interdepartmental coordination, refining production scheduling, evaluating production processes, and conducting training and evaluations to enhance operator skills.

Keywords: Rood Cause Analysis, Waste Assessment Model, Analysis 5W+1H

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1. Introduction

With the rapid growth of the manufacturing industry in Indonesia, competition among companies has intensified [1]. To remain competitive, entrepreneurs must enhance their business performance and productivity by optimizing production processes through the implementation of lean manufacturing [2] [3]. Lean manufacturing aims to streamline production processes by eliminating non-value-added waste, categorized into 7 types for more efficient identification and improvement [4] [5].

PT. XYZ has started exporting its products to several countries including America, Europe, Asia, Africa, and Australia. Despite having a large production capacity and facing product specification variations, PT. XYZ still encounters challenges such as complex inventory management and high variability in product specifications. Complex inventory management complicates the efficient handling of diverse stock items, posing challenges such as predicting demand, risks of overstock or understock, and high storage costs. High variability in product specifications also affects quality consistency, production process efficiency, and customer satisfaction with diverse preferences. To address these challenges, it is essential to identify types of waste in the bolt production process. Evaluation is conducted to identify wastages needing improvement or having the greatest impact, prioritizing improvement actions[6]. The Waste Assessment Model (WAM) is used with matrices and comprehensive questionnaires for optimal waste identification outcomes [7] [8]. Based on this evaluation, the next step involves root cause analysis of wastages to formulate improvements aimed at reducing waste [9] in PT. XYZ bolt production process.

2. Methods

Data collection involved qualitative and quantitative methods, including in-depth interviews on seven types of production waste and their relationships, identifying major wastes: overproduction, inventory, defects, transportation, motion, waiting, and overprocessing. The questionnaire was filled out by 3 experts (production department head, production manager, and operations manager) to assess the frequency and impact of waste, serving as the basis for developing strategies to enhance production efficiency, reduce costs, and meet customer expectations. Troubleshooting steps include:

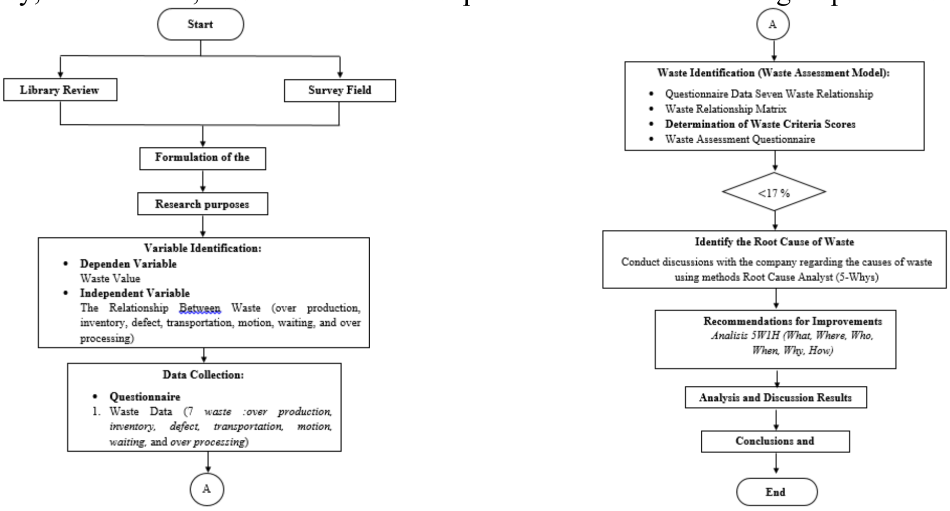

Figure 1. Research Methodology

Data processing at PT. XYZ involves identifying issues in bolt production, conducting a literature review, field studies, and using the Waste Assessment Model and Root Cause Analysis to identify and address waste. The study aims to recommend improvements for reducing waste through data collection via observations, interviews, and questionnaires. Next steps include formulating enhancement proposals using 5W+1H analysis to boost production efficiency.

3. Results and Discussion

3.1. Waste Asessment Model

3.1.1 Waste Relationship Matrix

Waste Relationship Matrix (WRM) is a matrix used to analyze measurement criteria[10]. Matrix waste it describes the real relationships between the different types waste[11]. The recapitulation of the weighting of the Waste Relationship Matrix of this research can be seen in Table 1 format:

Table 1. Weighted Recaps of WRM (Continue)

No	Notation	Average	Conversion
1	O_I	10	I
2	O_D	16	E
3	O_M	15	E
4	O_T	13	E
5	O_W	7	O
6	I_O	13	E
7	I_D	11	I
8	I_M	7	O
9	I_T	17	A
10	D_O	9	I
11	D_I	11	I
12	D_M	14	E
13	D_T	15	E
14	D_W	15	E
15	M_I	6	O
16	M_D	2	U
17	M_P	16	E
18	M_W	17	E
19	T_O	3	U
20	T_I	13	E
21	T_D	6	O
22	T_M	16	A
23	T_W	16	E
24	P_O	7	O
25	P_I	10	I
26	P_D	12	I
27	P_M	12	I
28	P_W	16	E
29	W_O	3	U
30	W_I	10	I
31	W_D	8	O

The table above shows the company's waste weight assessment results converted into letters. Results are categorized by relationships between waste types and organized into the Waste Relationship Value matrix, reflecting average weight conversion from the Waste Relationship Matrix (WRM). Below are the weighted average conversion results from three respondents in matrix format:

3.1.2 Waste Matrix Value

The Waste Matrix Value, derived from the weighted average WRM, is presented in Table 2

Table 2. Waste Matrix Value Letter Conversion Results

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

The table above depicts the Waste Relationship Matrix converted into letters, reflecting the score range and relationships between types of waste[12] [13]. Relationships between waste types are illustrated, such as the example from Overproduction (O) to Important (I) [14] 15]. Each letter is converted into a number based on predefined symbols: A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0 [16] . These numerical values are used for calculating waste weights [17]. Validating waste matrix values involves ensuring the consistency, accuracy, and representativeness of data on waste frequency and impact measurements, comparing them with industry standards or relevant historical data to ensure validity[18]. Below is the table showing the converted Waste Matrix Values:

Table 3. Waste Matrix Value Conversion Results

F/T	O	I	D	M	T	P	W	Skor	%
O	10	6	8	8	8	0	4	**44**	16,66%
I	8	10	6	4	10	0	0	**38**	14,39%
D	6	6	10	8	8	0	8	**46**	17,43%
M	0	4	2	10	0	8	8	**32**	12,12%
T	2	8	4	10	10	0	8	**42**	15,91%
P	4	6	6	6	0	10	8	**40**	15,16%
W	2	6	4	0	0	0	10	**22**	8,33%
Skor	**32**	**46**	**40**	**46**	**36**	**18**	**50**	**264**	100%
%	12,12%	17,42%	15,16%	17,42%	13,64%	6,82%	17,42%	100%	

Based on the data from the presented table, it can be observed that overproduction waste significantly influences other wastes by 16.66%. On the other hand, waste leading to overproduction receives influence from other wastes by 12.12%. Furthermore, inventory, motion, and waiting wastes also demonstrate significant influence on the generation of other wastes, totaling 17.42%. This analysis highlights the importance of understanding how one type of waste can impact others in the context of waste management in production environments.

3.2 Waste Assessment Questionaire

Table 4. Final Result of Waste Assessment Questionnaire Calculation

	O	I	D	M	T	P	W
Score (Yj)	0.134	0.147	0.122	0.118	0.141	0.071	0.116
Pj Factor O	0,02	0,025	0,026	0,021	0,02	0,01	0,014
Results (Yj Final)	0.00268	0.00368	0.00317	0.00248	0.00282	0.00071	0.00162
Final Result (%)	15,61%	21,44%	18,47%	14,46%	16,44%	4,13%	9,45%
Ranking	**4**	**1**	**2**	**5**	**3**	**7**	**6**

Based on the table above, the highest to lowest waste in the production process of PT XYZ starts with inventory, which has a final score of 0.00368, accounting for 21.44%, followed by defect with a final score of 0.00317, accounting for 18.47%, transportation with a final score of 0.00282, accounting for 16.44%, overproduction with a final score of 0.00268, accounting for 15.61%, motion with a final score of 0.00248, accounting for 14.46%, waiting with a final score of 0.00162, accounting for 9.45%, and overprocessing with a final score of 0.00071, accounting for 4.13%. This indicates that inventory and defect wastes are categorized as the highest wastes, with inventory waste being the most dominant because presentase waste ≤ 17%[19] [20].

3.3 Cause Analysis Waste Using RCA For Waste Inventory & Defect

The waste that will be observed is the waste with the highest percentage based on results Waste Assessment Model that is Inventory and defect. Search for the root of the problem is carried out using the 5 Why's tool.

Table 5. Analyze 5 Why of Waste Inventory

Sub Waste	Why1	Why 2	Why 3	Why 4	Why 5
Accumulation of excess product	The product in process (WIP) that has been processed has not been named.	There have been no revisions to the drawings from Engineering	*Revision of shop drawings* takes longer		
	Employing operators who currently have no work	*Deadline* production is getting closer	There are no changes to the timeline from *client*	Lack of coordination between departments	
Stacking of raw materials	There is a minimum limit for sending goods from suppliers	More raw materials are ordered than required for production due to high product demand			
Accumulation of Defective Products	Demand from clients is increasing.	An error occurred in the production process.	Lack of focus of production operators in carrying out tasks.	High workload.	
Stacking of semi-finished products (WIP)	Inhibited material handling	Transportation access is hampered by other material handling equipment.	Delay in available resources	Congestion (*bottleneck*) in the next process in the production flow	

Table 6. Analyze 5 Why of Waste Defect

Sub Waste	Why 1	Why 2	Why 3	Why 4	Why 5
Product Does Not Conform to Specifications	Production operators lack concentration on their tasks	Production capacity exceeds machine capacity.	Demand from clients is increasing		
		Demand from clients is increasing	High workload		
	Changes have been made to the shop drawings that guide operators in the production process.	There was a design change from the client			
Defective WIP Products	Foreman who is not focused when explaining tasks (during the production process)	Demand from clients is increasing	High workload		

Research indicates that the root causes of Waste Inventory are categorized into four types: excess inventory due to approaching production deadlines without schedule changes from clients and lack of inter-departmental coordination; stockpiling of raw materials due to orders exceeding production needs driven by high product demand; accumulation of defective products due to errors in the production process and lack of operator focus; and accumulation of work-in-progress (WIP) due to delays in resource availability and bottlenecks in subsequent production flow. The root cause of waste defects is attributed to operator focus issues stemming from high workloads.

3.4 Alternative 5W+1H Improvement Recommendations

Waste Inventory and waste defect which occupy first and second positions in the bolt production process at PT XYZ with percentage levels of 21.44% and 18.47%. The following is a 5WIH analysis table to formulate recommendations for improvements to problems waste Inventory dan waste defect:

Table 7. Recommendations for Waste Iventory Repair Alternatives

What	Where	Who	When	Why	How
Excess product buildup	Implementation Section	operator	During the production process, the implementation part	Delay in revision of drawings from parties *engineering* and lack of coordination between departments	Improved interdepartmental coordination, structured production scheduling, and effective client communication aim to prevent excessive product buildup nearing deadlines.
Stacking of Raw Materials	Preparation Section	Oprator	During the production process, the preparation section	Occurs because orders exceed production needs, along with high product demand.	Enhance inventory planning through accurate analysis, effective monitoring, and stronger supplier collaboration for better order flexibility
Accumulation of defective products	Implementation Section	Oprator	During the production process, the implementation part	Operators are not focused on carrying out their duties	Increase operator training, evaluate production processes, optimize resource use, and continuously improve quality control.
Stacking of semi-finished products (WIP)	All parts of the production process	Oprator	During the production process, the implementation part	Stacking of semi-finished products occurs due to delays in resource availability	Improve resource management by optimizing inventory planning and monitoring

Table 8. Recommendations for Waste Defect Repair Alternatives

What	Where	Who	When	Why	How
Product does not meet specifications	Implementation Section	operator	During the production process, the implementation part	High Workload	Review and enhance production capacity planning, and conduct training to improve operator skills.
Defective semi-finished products (WIP).	Implementation Section	operator	During the production process, the implementation part	High Workload	Review and enhance production capacity planning, and conduct training to improve operator skills.

The company can reduce inventory waste by improving departmental coordination, structured production scheduling, effective client communication to avoid product accumulation, inventory monitoring, supplier collaboration, operator training, production process evaluation, resource optimization, and quality supervision. For waste defects, the company can enhance operator skills through training.

4. Conclusion

The Waste Assessment Model (WAM) research results indicate that the highest wastes in bolt production are Inventory (21.44%) and Defects (18.47%). The root causes of Inventory Waste include excessive product accumulation due to nearing production deadlines without schedule changes from clients, lack of inter-departmental coordination, excessive raw material accumulation due to high demand, defective product accumulation due to process errors and operator distractions, and unfinished product accumulation due to delayed resources and process bottlenecks. Through a 5W1H analysis, the company can reduce inventory waste by improving departmental coordination, implementing structured production scheduling, enhancing communication with clients, effective inventory monitoring, better supplier collaboration for flexible orders, operator training, production process evaluation, resource optimization, and continuous quality supervision. To address defect waste, the company can enhance operator skills through training.

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