

## Minimization of Defects in the Loading and Unloading Process of Gallon Water Using a Lean Manufacturing and Value Stream Mapping Approach

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**Abstract**— Logistics processes, particularly in the loading and unloading area, pose a critical challenge for the Bottled Drinking Water (AMDK) industry, as they have the potential to reduce profitability due to waste. This study aims to eliminate non-productive activities in the distribution line of PT XYZ using a Lean Manufacturing approach. By integrating Value Stream Mapping (VSM) into map process flows and the Waste Assessment Model (WAM) to weight operational issues, this study examines the company's operational problems. The identification results indicate that defect is the most dominant form of waste, contributing 24.37% of the total waste variability, which significantly hampers distribution flow. Root Cause Analysis (RCA) highlights employee discipline and operational work instructions as the primary factors causing these defects. As a mitigation strategy, this study formulates improvement recommendations based on restructuring work instructions and strengthening employee discipline standards to reduce defect rates and accelerate service lead time.

**Index:** Defect; Lean Manufacturing; Loading-Unloading; Value Stream Mapping

### I. INTRODUCTION

The Bottled Drinking Water (AMDK) industry in Indonesia is facing increasingly intense competitive pressure, in which supply chain efficiency has become a key determinant of corporate competitiveness. Operating in a highly dynamic market environment with thin profit margins, supply chain efficiency serves as a critical factor in sustaining competitive advantage. While many companies focus on improving efficiency in filling and packaging production lines, downstream logistics activities, particularly the loading and unloading processes, are often

overlooked. In fact, inefficiencies at this stage increase delivery lead time to customers and elevate the risk of damage to finished products that are ready for sale. In AMDK distribution, the smooth flow of products from warehouses to transportation fleets plays a crucial role in determining customer service lead time. [Nurhayati, 2021] However, logistics activities, especially during the loading and unloading stages, frequently become significant bottlenecks. Disorganization in these processes not only leads to delivery delays but also increases the risk of product damage and unnecessary operational costs. [Mapping et al,2000]. Therefore, mapping non-value-added activities is essential for companies seeking to maintain profitability.

PT XYZ, as a growing AMDK producer, faces serious challenges in its distribution operations. Based on preliminary observations in the finished goods warehouse area, the transfer of gallon products to distribution fleets is still carried out manually and semi-automatically, making it highly susceptible to waste. This waste is reflected in the high frequency of defective products during loading and the fluctuating waiting time of transportation fleets. Company data indicate that a significant number of defects, in the form of cracked or broken gallons, occur during the loading process rather than during production. These damages force operators to perform rework or product replacement, which directly interrupts the distribution flow and causes waiting time for truck fleets. This condition creates a domino effect, including disrupted delivery schedules, increased operational costs due to overtime and product replacement, and potential complaints from distributors as a result of delays. If this waste is not promptly eliminated, the company risks losing market growth momentum due to internal inefficiencies. This situation indicates that the company's value stream is not operating optimally and, if left unaddressed, will continuously erode

productivity and customer satisfaction. [Tiara&Siagian,2024].

To address these issues, the Lean Manufacturing approach offers a systematic framework for identifying and reducing waste. One of the most effective Lean tools for mapping material and information flows is Value Stream Mapping (VSM) [woofuru\_enyek, 2019]. Although VSM is highly effective for visualization purposes, this method has limitations in quantitatively measuring the weighted interrelationships among different types of waste. Therefore, integrating VSM with the Waste Assessment Model (WAM) is necessary to provide a more precise understanding of the root causes. [Pwagung et al, 2024]. WAM complements VSM by simplifying the relationships among different types of waste, thereby allowing improvement priorities to be determined objectively.

Previous studies have extensively discussed the implementation of Lean in manufacturing production lines; however, studies that specifically integrate Value Stream Mapping (VSM) and the Waste Assessment Model (WAM) in the loading and unloading area of AMDK products remain limited [cerez, 2019]. This study aims to address this gap by conducting an in-depth analysis of the distribution process flow at PT XYZ. The primary focus of this research is to identify the most influential waste, analyse its main causal factors using Root Cause Analysis, and formulate improvement strategies to minimize defects and accelerate the loading and unloading process. The results of this study are expected to provide practical contributions to improving the company's logistics system and serve as an academic reference for the application of Lean in the AMDK distribution sector.

## II. RESEARCH METHOD

This study maps the loading and unloading process to identify waste using a Lean Manufacturing approach. The primary method employed is Value Stream Mapping, which consists of the following stages:

### 1. Current State Mapping

Current State Mapping is used to observe all activities in the loading and unloading process by mapping all physical and information flows and calculating the time required for each

activity (cycle time). Based on the cycle time analysis, activities are classified into Value-Added (VA) activities and Non-Value-Added (NVA) activities. [Lu & Aidil, 2024]

### 2. Waste Assessment Model (WAM)

To measure the severity level of each type of waste, including overproduction, defect, motion, transportation, waiting, inventory, and overprocessing, weights are assigned using the WAM factor scale by ranking the waste from the highest to the lowest priority.

### 3. Waste Relationship Matrix (WRM)

The Waste Relationship Matrix is used to analyze cause-and-effect relationships among different types of waste by assessing the level of influence between wastes on a scale of 1 to 4 [Kurangi et al, 2024]. This assessment generates the symbols A, E, I, O, and U, which are then used to determine the driving waste that exerts the greatest influence. As a result, the waste that constitutes the root cause of the problem can be identified.

### 4. Waste Assessment Questionnaire (WAQ)

The Waste Assessment Questionnaire is administered to evaluate the frequency of waste occurrences and to validate the results of observations and the Waste Assessment Model. WAQ results are calculated using weighted scores, where 1 represents Yes, 0.5 represents Moderate, and 0 represents No. Consequently, each type of waste is assigned a quantitative value.

### 5. Root Cause Analysis (RCA)

After the most significant waste has been identified, Root Cause Analysis is conducted using a Fishbone Diagram and the 5 Whys Analysis to determine the root causes and to formulate improvement recommendations.

### 6. Future State Mapping (FSM)

Future State Mapping is developed based on the results of the Root Cause Analysis through the following stages:

- Designing a more efficient process
- Eliminating Non-Value-Added (NVA) activities
- Reducing cycle time in Value-Added (VA) activities
- Developing a new value stream map with minimal waste.

The following is the flow diagram of this study:

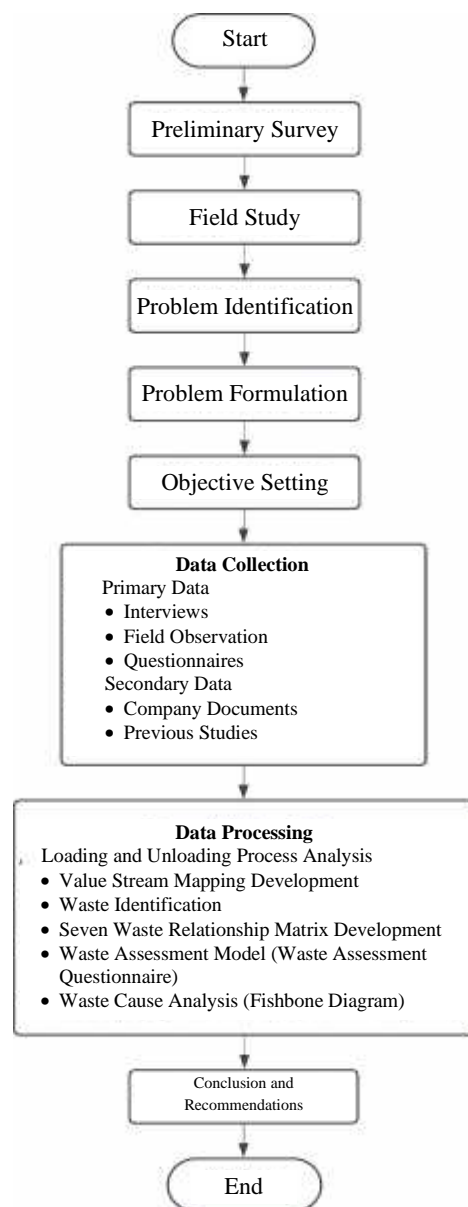


Figure 1. Research flowchart

Based on the diagram above, the development of Value Stream Mapping facilitates a more comprehensive identification of the seven types of waste, namely overproduction, waiting, transportation, overprocessing, inventory, motion, and defect. Each type of waste is represented by specific indicators and measurement criteria, allowing waste to be identified more effectively. [Lubis et al, 2025]

### III. RESULTS AND DISCUSSION

The initial step of this study was to map the physical and information flows of the loading and unloading process at PT XYZ using Current State Mapping (CSM). Based on field observations, the distribution process begins with order receipt, followed by product retrieval from the finished goods warehouse, and concludes with loading onto transportation fleets.

The CSM analysis in Figure 2 reveals a significant presence of Non-Value-Added (NVA) activities along the distribution flow. The total cycle time of the loading process exhibits high variability, primarily caused by frequent line stoppages due to material accumulation and errors in manual handling. The proportion of Value-Added (VA) activities is currently recorded at 63%, while the remaining time is dominated by Necessary but Non-Value-Added (NNVA) activities and pure Non-Value-Added (NVA) activities. This condition indicates inefficiencies in the logistics flow that require immediate reduction.

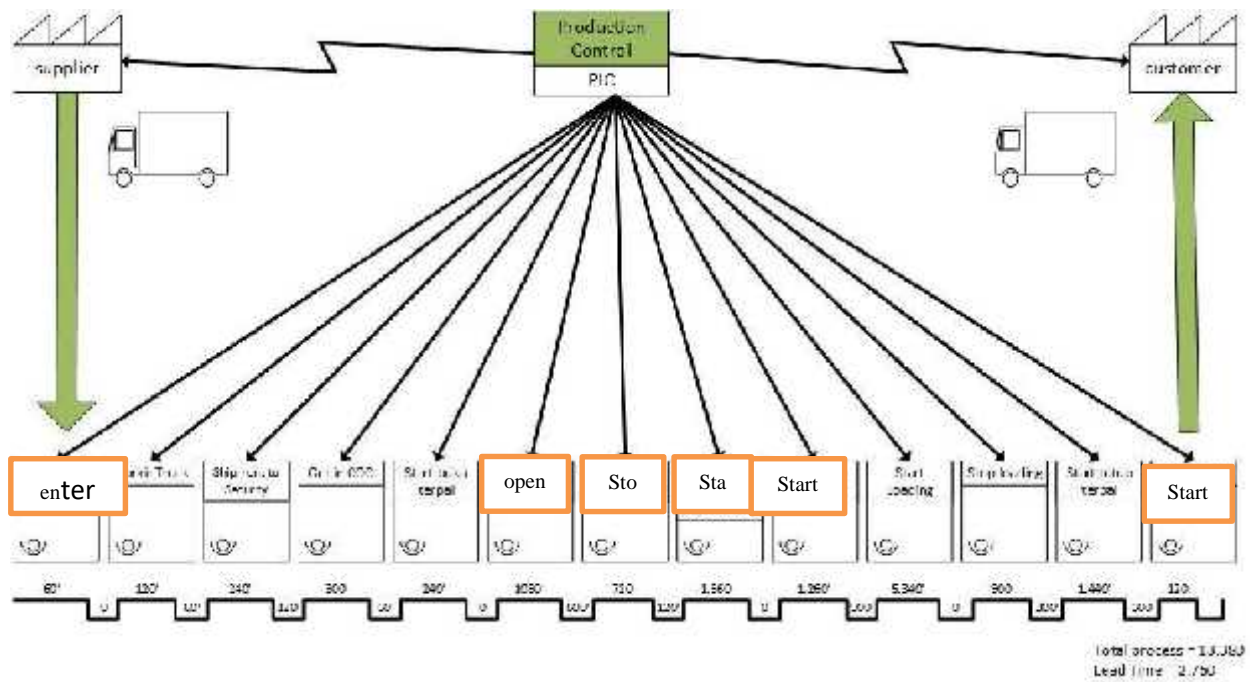


FIGURE 2. CURRENT STATE MAPPING

After establishing the Current State Mapping condition, waste identification can be conducted through the following steps:

1. Identification of Critical Waste Using the Waste Assessment Model (WAM)

This stage aims to determine improvement priorities in the most objective manner. As

shown in Table 1, the waste that most significantly triggers the emergence of other waste is defect, with a contribution of 8.13%. Meanwhile, the waste most heavily affected by other wastes is waiting, with a contribution of 9.57%

Table 1. Waste Assessment Model

	Overproductio n	Inventor y	Defec t	Motio n	Transportatio n	Proces s	Waitin g	Scor e	%
Overproductio n	10	4	4	4	4	0	4	30	7.18
Inventory	4	10	2	6	4	0	0	26	6.70
Defect	2	4	10	6	6	0	6	34	8.13
Motion	0	2	4	10	0	8	4	30	6.70
Transportation	2	4	6	4	10	0	8	34	8.18
Process	2	2	4	8	0	10	8	34	8.18
Waiting	4	2	6	0	0	0	10	22	5.26
Score	24	28	36	38	24	18	40	418	
%	6.22	6.70	8.61	9.09	5.57	4.31	9.57		

The recapitulation of the final WAM scores indicates that defect is the most dominant type of waste, with a contribution of 24.37%. This high defect rate primarily occurs during the transfer of gallon products from the conveyor to the truck, where the gallons frequently experience collisions, cracking, or breakage. The second most dominant waste consists of unnecessary activities, namely waste of motion and waiting, which contribute approximately 8% to the total inefficiency. These findings confirm that the primary focus of improvement efforts should be directed toward reducing product damage in order to enhance overall efficiency.

## 2. Process Activity Mapping

To further examine the structure of inefficiencies identified in the Current State Mapping, a more detailed analysis was conducted using Process Activity Mapping (PAM). PAM decomposes each work step in the loading and unloading process into five activity elements, namely Operation, Transportation, Inspection, Delay, and Storage. Based on Table 2, which presents the mapping results of all activities occurring on the shop floor, the following activity composition was identified:

Table 2. Process Activity Mapping

Activity	Frequency	Time
Operation	13	136
Transportation	6	27
Inspection	3	4
Storage	1	15
Delay	8	60
VA	8	153
NNVA	18	70
NVA	5	19
<b>TOTAL TIME(minutes)</b>	<b>242</b>	
<b>%VA</b>	<b>63%</b>	
<b>%NNVA</b>	<b>29%</b>	
<b>%NVA</b>	<b>8%</b>	

*Value Added – VA:* VA activities account for 63% of the total process time. These activities include core operations such as retrieving gallon products from pallets and arranging them inside the truck. Although VA activities dominate the process, this proportion indicates that nearly 40% of operators' working time is still consumed by non-productive activities.

*Non-Value Added – NVA:* NVA activities are identified as relatively significant, primarily dominated by transportation and delay elements. The transportation waste arises from the relatively long manual handling distance between the end of the

conveyor and the truck bed, which forces operators to perform excessive and unnecessary walking movements.

*Necessary but Non-Value Added – NNVA:* NNVA activities include brief visual inspections and the rearrangement of misaligned gallons. These activities do not add value to the product from the customer's perspective; however, they are unavoidable due to limitations in the current work system.

This Process Activity Mapping confirms the findings of the previous Waste Assessment Model (WAM) analysis. The high proportion of Non-Value-Added (NVA) activities,

particularly transportation and waiting, shows a strong correlation with the occurrence of defect waste. [ansyah&Kustiwan, 2025]. Operator fatigue resulting from excessive manual transportation activities has been identified as a latent factor that reduces work focus, thereby increasing the risk of gallons slipping or breaking during the loading process due to rough handling. Therefore, improvement strategies should not focus solely on machine-related enhancements, but also on redesigning the workplace layout to reduce transportation distances and eliminate unnecessary movements

### 3. Root Cause Analysis

After identifying defect as the most critical type of waste, with a contribution weight of 24.37% based on the Waste Assessment Model (WAM), the next step was to diagnose the root causes of this issue. The analysis was conducted using a Cause-and-Effect Diagram to examine the factors contributing to the high rate of gallon damage during the loading process. [Issu et al, 2023]

- **Man:** Human factors were identified as the dominant contributors to process variability. Based on observations and interviews, two critical issues were identified. The first is physical fatigue resulting from workload, where the high level of transportation activities involving manual handling of gallon products, as revealed by the PAM analysis, leads to accumulated operator fatigue. This fatigue reduces concentration levels and motor control during lifting activities, thereby triggering rough handling that results in gallons slipping or colliding with the sides of the truck bed. The second issue is a lack of discipline and focus, reflected in inconsistencies among operators in maintaining a stable working pace. During critical periods prior to breaks or shift changes, operator focus tends to decline, increasing the frequency of product handling errors.
- **Method:** The current work system and procedures contain gaps that allow variations in work practices among operators, particularly due to non-ergonomic work instructions. The

Based on the results of the Root Cause Analysis, defects at PT XYZ are not isolated incidents, but rather the outcome of a systemic interaction between operator fatigue, caused by physically demanding manual work methods, and insufficient machine precision. Therefore, partial

existing loading Standard Operating Procedures (SOPs) are overly general and do not regulate ergonomic lifting techniques suitable for high-speed operations. As a result, each operator develops an individual lifting style, which is often unsafe for both product integrity and operator health. Furthermore, the absence of standardized procedures for rapid handling during conveyor congestion leads operators to take impulsive actions, such as forcibly pulling jammed gallons, which further exacerbates the risk of product damage [Rauch, 2022].

- **Machine:** Supporting infrastructure, particularly the conveyor system, constitutes a technical factor that hinders smooth material flow. Conveyor belt instability, resulting from fluctuating motor performance, frequently causes sudden jerking movements. This condition leads to collisions among gallons on the conveyor before they reach the loading dock, resulting in micro-cracks on the gallon body. In addition, insufficient preventive maintenance is indicated by the frequent occurrence of minor downtime due to mechanical congestion, suggesting that the machine maintenance schedule has not been optimally implemented to anticipate component wear. [Utami et al, 2023]

**Environment:** The physical condition of the work area further exacerbates the potential for defects. The limited maneuvering space at the loading dock restricts operator movement during material handling [Abdullah, 2022]. This confined space forces operators to perform risky body-twisting movements, thereby increasing the likelihood of collisions between gallons and surrounding structures such as walls or support pillars. In addition, uneven floor conditions and suboptimal lighting inside the truck bed in several areas make it difficult for operators to arrange gallons with precision, thereby increasing the risk of unstable stacking and collapse.

solutions such as merely reprimanding operators will not be effective. A comprehensive intervention is required, encompassing improvements in work ergonomics, including workplace re-layout to reduce material handling distances, as well as technical improvements to the

conveyor system to maintain product flow stability.

4. Future State Mapping

Future State Mapping is designed by implementing three main interventions to improve the flow of materials and information.

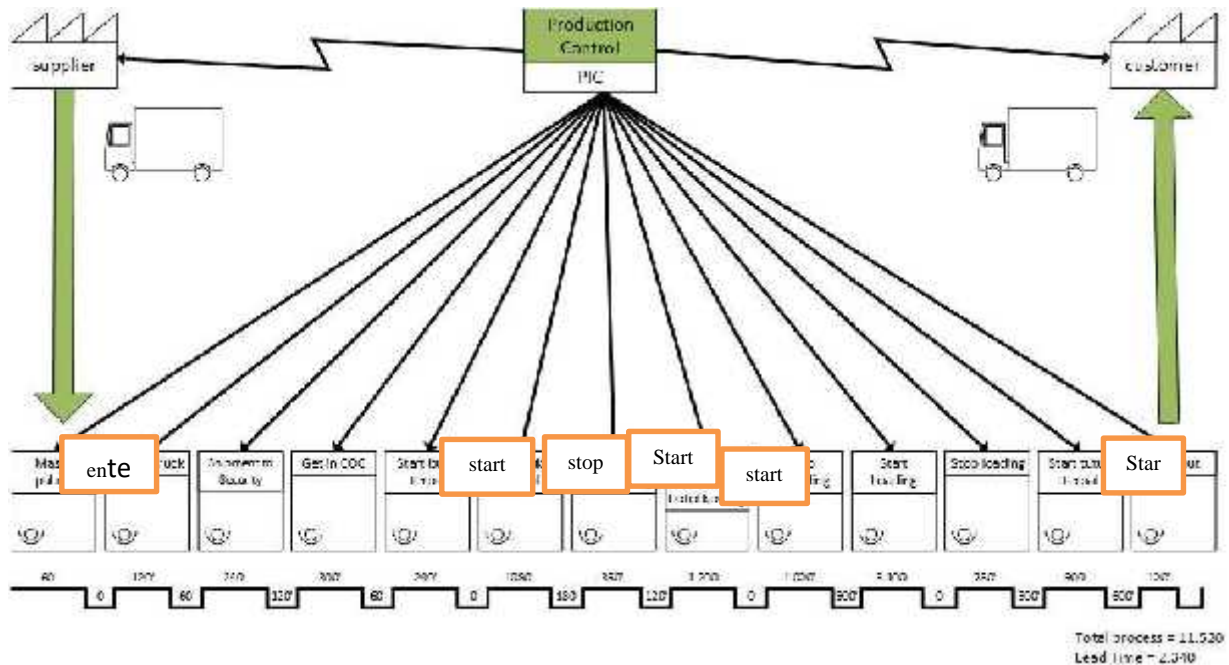


Figure 3. Future State Mapping

Based on the results of the Future State Mapping, the proposed improvements derived from the Process Activity Mapping (PAM) analysis are as follows:

- Technical Improvement of the Conveyor Line (Machine Reliability): In the future state map, the implementation of a preventive maintenance schedule is proposed, specifically for conveyor supports and motors. This measure aims to eliminate incidents of conveyor jamming, which have been the primary cause of gallon accumulation and product-to-product collisions. With reliable machinery, material flow becomes continuous, allowing waiting time caused by machine downtime to be reduced to zero.
- Work Standardization and Rest Break Management (Standardized Work): Current conditions indicate the presence of work variability due to operator fatigue and suboptimal rest break arrangements. In the Future State design, a more structured rotating rest break schedule is implemented to ensure that the loading workstation is

never left unattended or understaffed, while still allowing operators sufficient recovery time. In addition, new Standard Operating Procedures are introduced for ergonomic manual lifting techniques to prevent rough handling, which is a major cause of gallon breakage.

- Upstream Quality Control (Quality at Source): To address the issue of leaking or non-sterile gallons passing into the loading area, the inspection system is tightened in the production area before products enter the finished goods warehouse. This ensures that material inputs entering the loading process consist entirely of defect-free products, so loading operators no longer need to spend time sorting or replacing defective products on the truck.

The implementation of the proposed Future State design is projected to have a significant impact on the company's key logistics performance indicators. Through improvements in conveyor reliability and rest management, material accumulation along the distribution line can be eliminated [Songkhwa,

2025.] Product flow becomes smoother, transforming an unstable push system into a stable pull system.

With the elimination of Non-Value-Added activities such as waiting for conveyor repairs or replacing broken gallons, the proportion of effective operator working time increases.

#### IV. CONCLUSION

This study has successfully identified and analyzed sources of inefficiency in the loading and unloading process at PT XYZ using an integrative Lean Manufacturing approach. Through Value Stream Mapping and weighting using the Waste Assessment Model, it was revealed that the company's distribution flow is hindered by the dominance of Non-Value Added activities.

The key finding of this study concludes that defects represent the most critical form of waste, contributing 24.37 percent to total waste variability. The high defect rate is directly correlated with excessive waiting time and unnecessary motion. Root Cause Analysis confirms that operator fatigue caused by repetitive manual handling, non-ergonomic work instructions, and conveyor performance instability are the main factors leading to product damage during loading.

As a strategic solution, the Future State Mapping design recommends the implementation of preventive maintenance on conveyor infrastructure, standardization of ergonomic work methods, and improvement of operator rest schedule management. The implementation of these recommendations is projected to eliminate bottlenecks, minimize the risk of defective products, and significantly improve distribution cycle time efficiency. This study provides a practical foundation for PT XYZ management to transform toward a lean and highly competitive logistics system.

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