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Analysis of The Application of Lean Distribution on Urea Fertilizer Products in Minimizing Waste with Arena Simulation (Case Study: PT. Pupuk Iskandar Muda, North Aceh)

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Abstract. *PT. PIM is a company operating in the fertilizer industry. The main issue lies in prolonged lead times within the distribution process, causing inefficiencies and resulting in waste during distribution activities. The concept of Lean Distribution focuses on managing strategic distribution processes effectively and efficiently to reduce waste. The results of Big Picture Mapping and Process Activity Mapping identified six distribution groupings involving 20 activities with a total time of 343 minutes. Waste identification using Arena Simulation revealed three activities experiencing waiting time (waste): unloading goods (428.41 minutes), placing fertilizer onto trucks (55.55 minutes), and truck inspection at the warehouse (0.38 minutes). Proposed improvements include reducing time in activity 6 by 9%, activity 8 by 26%, and activity 20 by 28.8%. The results of the Arena Simulation indicate that scenario 6 achieves the highest efficiency, with a time reduction of 36.4%, resulting in a total time of 20 minutes.*

Keywords: *arena simulation, lead time, lean distribution, proposed 5W+1H improvements*

I. INTRODUCTION

The distribution channel is the path through which the flow of goods moves from producers to consumers. Distribution channels are critical to a company's business operations, influencing managerial decisions to provide excellent consumer service. The goal of distribution channels is not only to reduce costs but also to meet customer needs. Distribution is vital in ensuring that marketed products are always available across all regions (Samun J.R. & Ria A., 2013).

PT. PIM (Pupuk Iskandar Muda) is a company engaged in the fertilizer, petrochemical, and other chemical industries and services. The company is located in Krueng Geukueh, North Aceh, Indonesia. PT PIM produces Urea fertilizers and NPK fertilizers, with a distribution capacity of 39,908 tons in 2022. The company was established on February 24, 1982, under the Notarial Deed of Soeleman Ardjasasmita.

This research focuses on the distribution of subsidized urea fertilizer. There is no lead time difference between subsidized and non-subsidized fertilizers within the distribution process. PT PIM utilizes both land and sea distribution channels, operating 27 distribution warehouses across the North Sumatra Region (Sumbagut). Land routes cover the Aceh and North Sumatra areas, while sea routes serve West Sumatra, Riau, and the Riau Islands. The research scope is limited to the land-based distribution process from Line 1 Warehouse (PT PIM) to Line 3 Warehouse (Lhokseumawe).

The distribution issue faced by PT. PIM lies in the prolonged lead time during the distribution process due to limitations in executing distribution activities. As a result, the company must ensure timely fertilizer deliveries. Delays in the distribution process are caused by disruptions in the distribution activities from the Line 1 Warehouse to the Line 3 Warehouse, leading to waste in the distribution process.

Previous studies have provided several references related to research on lean

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distribution. Delays in product delivery are often caused by non-value-added activities or waste, addressed by minimizing waste in delivery lead times (Lavenia H. & Handoko, 2020). Research on the implementation of Lean Distribution to reduce lead time has utilized Value Stream Analysis Tools (VALSAT), a tool designed to minimize waste in work processes, along with the "5 Whys" method to identify waste and propose improvements (Tirtana S. & Puar, 2018). Additionally, a study analyzed product delivery lead times to optimize distribution routes using the Lean Distribution approach, employing Arena software to simulate and develop improvement scenarios (Umar W., 2016).

The research process begins by analyzing the distribution flow and distribution activities, with data obtained from primary and secondary sources. After collecting the data, time measurement is conducted by performing data uniformity and adequacy tests. Subsequently, Big Picture Mapping and Process Activity Mapping are created to describe PT. PIM's distribution activities. The distribution process flow is then modeled using Arena Simulation to identify waste, summarizing all flows and activities within the distribution process by identifying waiting times at each distribution stage. Once the waste is identified, improvement proposals are developed using the 5W+1H method (What, Who, When, Why, Where, and How) based on references to enhance time efficiency. Following the improvement proposals, Lean Distribution is implemented using Arena Simulation to test and determine the best scenario for adopting Lean Distribution. This approach aims to reduce the prolonged lead time issues and achieve a more efficient distribution process after implementing Lean Distribution.

II. RESEARCH METHOD

The method used is Lean Distribution, which incorporates several tools, including Big Picture Mapping, Process Activity Mapping, Waste Identification, and 5W+1H Improvement Proposals. The implementation utilizes Arena Simulation to model the distribution process flow and determine the best scenario for applying Lean Distribution. The research begins by identifying the issues occurring at PT. PIM. After identifying the problems, field studies and literature reviews related to the topic and methodology are conducted. The following is the research flowchart for analyzing Lean Distribution implementation to minimize waste using Arena Simulation at PT. PIM.

In the data processing stage, the process begins with a data uniformity test to ensure that the collected data comes from the same system. Additionally, this test is necessary to separate data with different characteristics (Yanto & Ngaliman B., 2017). The data uniformity test uses cycle time obtained through measurements using the downtime method for each work activity. The test is performed with upper control limits (UCL)

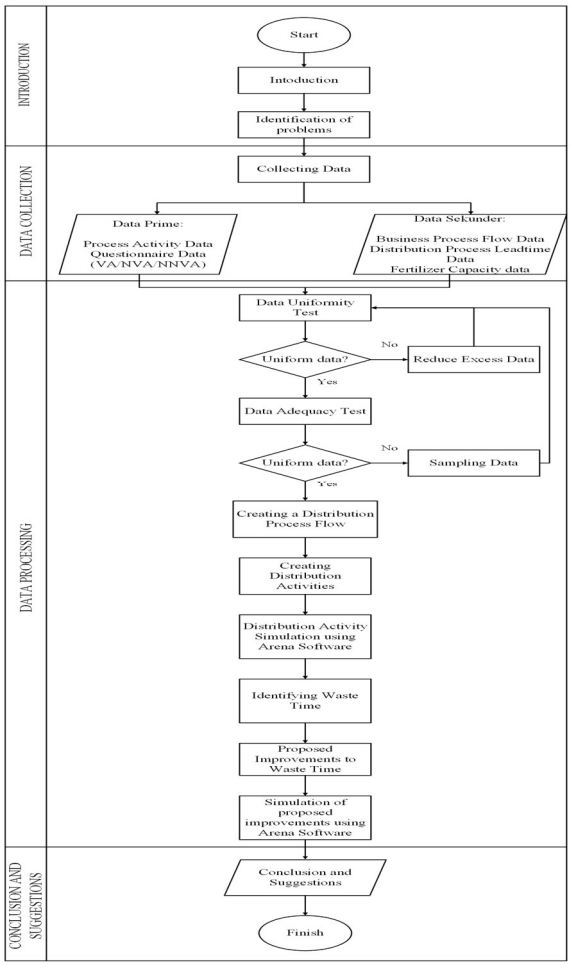


Figure 1. Research Flowchart

and lower control limits (LCL). Data that exceeds these limits will be considered non-uniform and must be discarded.

After performing the data uniformity test and confirming that the data is uniform, the next step is to conduct a data adequacy test to ensure that the collected data is sufficient and objectively represents the population being studied (Purnomo H., 2004). A sample of the data is taken for calculation to determine whether the data represents the entire population. The results of this test will be used to calculate the normal time and standard time for the warehouse activity processes.

Distribution process flow is created to analyze each fertilizer distribution process in greater detail, examining each step and time in the form of a Big Picture Mapping Diagram, which is a tool used to map processes at a high level, encompassing broad processes (Hines P. & Taylor D., 2000). This diagram is created by describing each stage of the distribution process from upstream to downstream, incorporating time data. The output of this process includes the lead time at each stage of the distribution process.

The distribution activities are created to observe the processes carried out during distribution activities in the form of a table. Process Activity Mapping is a technical approach used for activities on the production floor (Karundeng T. & Mandey S., 2018). This diagram is designed to detail each distribution process activity, map the distribution flow, determine the value and non-value of each distribution activity, and categorize waste based on Value Add (VA), Non-Value Add (NVA), and Necessary Non-Value Add (NNVA).

In this process, the distribution flow, based on its activities, is implemented in Arena Simulation to model and engineer the system to determine the optimal representation of a specific object (Frans R & Suharsono D., 2013). This allows for simulating and analyzing different processes or systems visually and interactively.

In this process, waste identification is made based on data from the simulation software, which includes the distribution process flow and its associated times in Arena Simulation software, leading to the identification of waiting time that can be considered waste. Once the waste is identified, a cause-and-effect analysis is conducted based on data from interviews and observations.

After identifying the waste, improvement suggestions are made using the 5W+1H method, which is an action plan that clearly outlines each corrective action or quality improvement (Tirtana Siregar, M., & Puar, 2018). The 5W+1H approach is used to propose solutions for minimizing waste in the distribution process by altering actions or other factors.

Once the improvement proposals are made, a simulation is created using Arena Software, which is a flexible tool for analysis that allows for the creation of accurate simulation models to

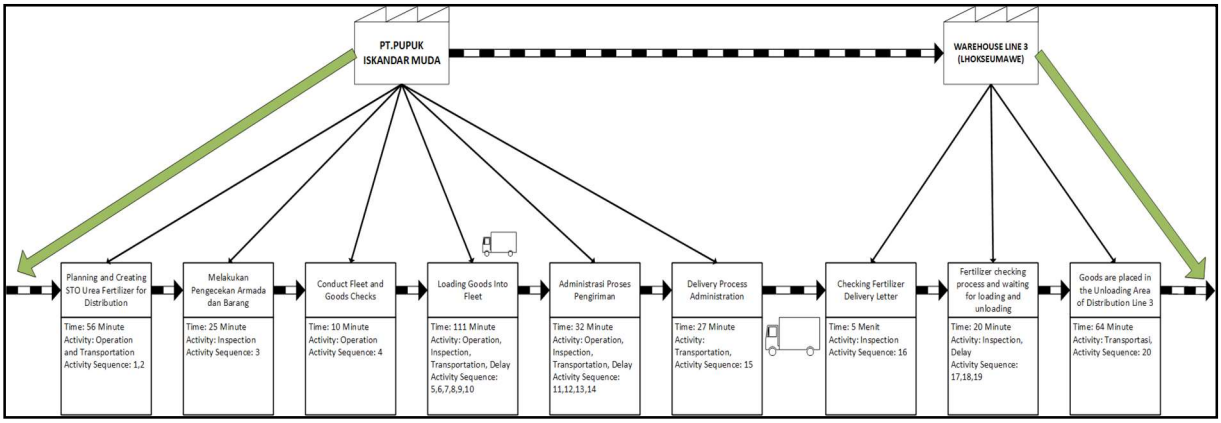


Figure 2. Big Picture Mapping

virtually represent the system (Umar W., 2016). Arena software is used to evaluate improvements and directly implement the best scenario based on the results of this research.

III. RESULT AND DISCUSSION

The sequence of data collection results is followed by data processing, including the uniformity test and data adequacy test, to determine the distribution process time. Once the time is determined, a Big Picture Mapping diagram can be created to describe each stage of the distribution process from upstream to downstream, including the time data. The Big Picture Mapping diagram of the distribution process can be seen in Figure 1.

Table 1. Process Activity Mapping

No	Land Route Activities	Time	Number of Workers	Activity					VA/NVA /NNVA
				O	T	I	S	D	
1	The PIM party determines the Sales and Operation Planning to decide the fertilizer shipment capacity.	45	All related work units	O					VA
2	The distribution party creates a Stock Transfer Order for the physical transfer of fertilizer via the land transport fleet.	11	1	O					VA
3	The PIM party will check the availability of goods and fleet.	25	1			I			VA
4	The distribution party creates a picking list for the fertilizer capacity.	10	1	O					VA
5	Wait for the truck's arrival at the Warehouse.	5	1					D	NVA
6	Truck inspection before entering the Warehouse area.	12	1			I			NNVA
7	The truck enters the Warehouse area.	10	1		T				VA
8	The fertilizer is loaded by the picker and placed onto the truck.	54	3 people/ truck	O					VA
9	The amount of fertilizer loaded is counted and re-checked by the distribution party.	17	1			I			VA
10	Truck inspection after entering the Warehouse area.	13	1			I			NNVA
11	Wait for confirmation from the distribution party (data entry into the system).	8	1					D	NVA
12	The distribution party creates the shipping order document.	10	1	O					NNVA
13	The distribution party gives the shipping order document to the driver.	4	1		T				NNVA
14	The truck is re-inspected before departing from PT. PIM.	3	1			I			NNVA
15	The truck departs to deliver goods to Line 3 Warehouse.	27	1		T				VA
16	The distribution party at PT. PIM checks the shipping documents.	5	1			I			VA
17	Truck inspection at the Warehouse area of Line 3 Warehouse.	5	1			I			NNVA
18	Wait for unloading preparation at the Line 3 Warehouse.	6	1					D	NVA
19	Count the amount of fertilizer to be unloaded into the Line 3 Warehouse.	9	8 people / truck			I			NNVA
20	The goods are placed in the unloading area of Line 3 Warehouse.	64		O					VA
	Total	343		6	3	8	0	3	

The diagram explains that the distribution process consists of 9 activities required to move goods from Warehouse Line 1 to Warehouse Line 3. These activities include planning and creating the Stock Transfer Order (STO), checking the fleet and goods, creating a picking list for fertilizer distribution, loading goods onto the fleet, shipment administration, delivering fertilizer to Warehouse Line 3, checking shipment documents, unloading goods at Warehouse Line 3, and placing goods in the unloading area at Warehouse Line 3. The estimated average time is 343 minutes, with 20 activities in each step.

Process Activity Mapping is conducted to map the entire activity process in detail at each stage of the distribution flow explained earlier. Below are the distribution process activities carried out by PT. Pupuk Iskandar Muda. In Process Activity Mapping, there are 20 activities in the distribution process from Warehouse Line 1 to Warehouse Line 3, with various types of activities. Table 1 shows the Process Activity Mapping.

Based on the results of the Process Activity Mapping, the activity with the highest time allocation is the operation activity, which consists of 6 tasks totaling 194 minutes, accounting for 56.6% of the time. This time is used for administrative processes and loading fertilizer onto the truck, as well as transportation. The second-highest activity is Inspection, consisting of 8 tasks totaling 89 minutes, which accounts for 25.9% of the time. This time is used for truck, fertilizer, and shipping document inspections. The third-highest activity is Transportation, which includes 3 tasks totaling 41 minutes, accounting for 12.0% of the time. This time is used for the truck entering the warehouse and delivering fertilizer to the Line 3 Warehouse. The lowest time allocation is for Delay activities, consisting of 3 tasks totaling 19 minutes, accounting for 5.5% of the time. This time is spent waiting for the truck's arrival and waiting for unloading at Line 3 Warehouse.

Based on the summary of the Process Activity Mapping, the activities classified as Value Add consist of 10 tasks totaling 268 minutes, accounting for 78.1% of the time. Non-Value Add activities consist of 3 tasks totaling 19 minutes, accounting for 5.5% of the time. Necessary Non-Value Add activities consist of 7 tasks totaling 56 minutes, accounting for 16.3% of the time. Below is a graphical representation of the summary from the Process Activity Mapping, showing the Value Add, Non-Value Add, and Necessary Non-Value Add categories

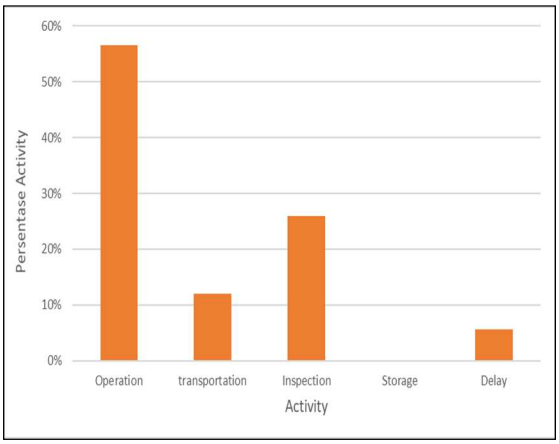


Figure 3. Graph of the number of activities in PAM

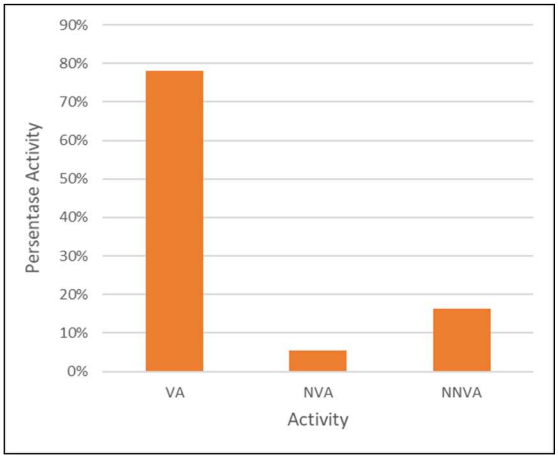


Figure 4. Graph of VA, NVA, NNVA

Simulation of distribution activities is a process of modeling and testing distribution scenario models using Arena Software to simulate real-world conditions. This simulation focuses on identifying any obstacles in the distribution process that could lead to delays. Below is the distribution activity flow at PT. Pupuk Iskandar Muda with the implementation of Arena Software simulation.

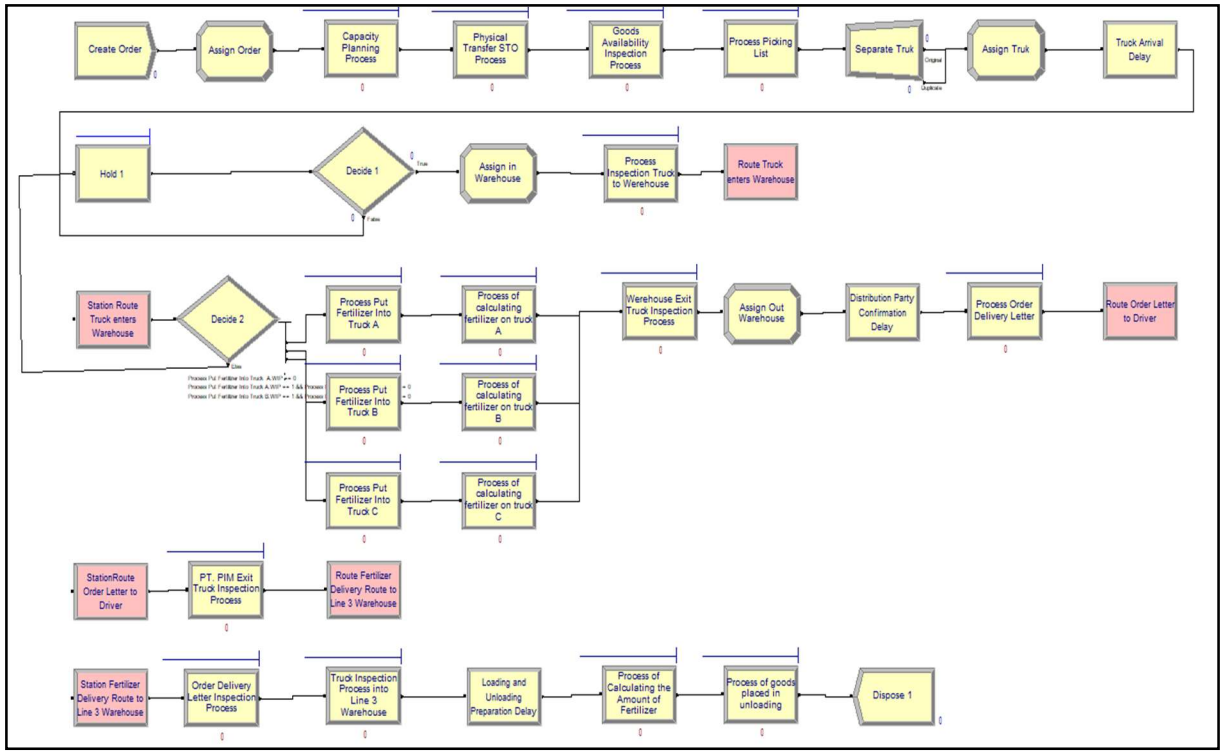


Figure 5. Simulation of the Distribution Process Flow

During the distribution process simulation using Arena Software, delays or obstacles were identified in three specific activities the truck inspection before entering the Warehouse area, the placement of fertilizer onto the truck, and the unloading of goods at the unloading area.

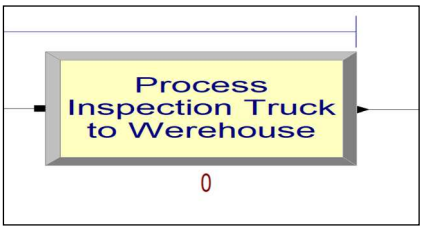


Figure 6. Truck Inspection Process Before Entering the Warehouse

In Figure 6, there is an obstacle in the distribution process during the Arena simulation. These delays may be caused by the fact that the truck inspection process is conducted by only one person, who checks both the truck and the vehicle documents, which takes 12 minutes. Next, the process of placing fertilizer onto the truck is done using a forklift.

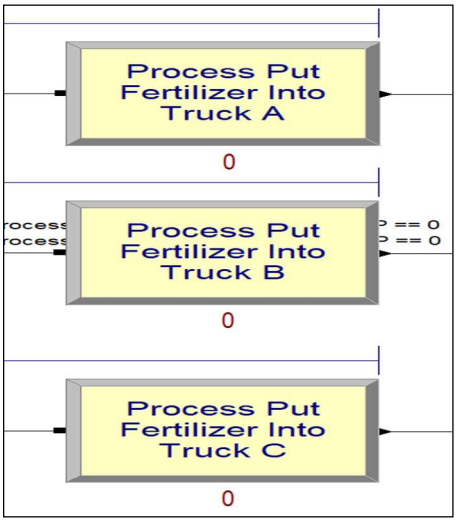


Figure 7. Process of Loading Fertilizer into Trucks

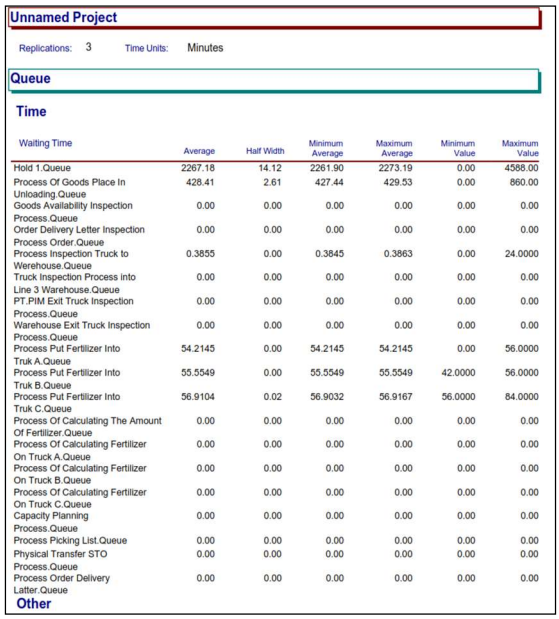
In Figure 7, there is an obstacle in the distribution process during the Arena simulation. In each process, 3 trucks are allowed to enter, as there are 3 doors at the Warehouse for loading the fertilizer. This delay may be caused by the fact that only one person is operating the forklift for loading the fertilizer onto the truck, while 2

people are responsible for stacking the fertilizer inside the truck, which takes 54 minutes per truck.

In Figure 8, there is an obstacle in the distribution process during the Arena simulation. This delay may be caused by the unloading process being done manually with 8 workers to unload the fertilizer from the truck to the Warehouse, which takes 64 minutes per truck. Below is the average waiting time value during distribution using the Arena Simulation.

Based on the analysis of waiting time from the Arena Simulation, three waiting times were identified: the time taken to place goods in the unloading area, with an average of 428.41 minutes; the time to load fertilizer onto trucks A, B, and C, with an average of 55.55 minutes; and the truck inspection time before entering the Warehouse, with an average of 0.38 minutes.

Figure 8. The process of goods being placed in unloading



Unnamed Project

Replications: 3 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Hold 1.Queue	2267.18	14.12	2261.90	2273.19	0.00	4588.00
Process Of Goods Place In Unloading.Queue	428.41	2.61	427.44	429.53	0.00	860.00
Goods Availability Inspection Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Order Delivery Letter Inspection Process Order.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Inspection Truck to Werehouse.Queue	0.3855	0.00	0.3845	0.3863	0.00	24.0000
Truck Inspection Process into Line 3 Warehouse.Queue	0.00	0.00	0.00	0.00	0.00	0.00
PT.PIM Exit Truck Inspection Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Warehouse Exit Truck Inspection Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Put Fertilizer Into Truk A.Queue	54.2145	0.00	54.2145	54.2145	0.00	56.0000
Process Put Fertilizer Into Truk B.Queue	55.5549	0.00	55.5549	55.5549	42.0000	56.0000
Process Put Fertilizer Into Truk C.Queue	56.9104	0.02	56.9032	56.9167	56.0000	84.0000
Process Of Calculating The Amount Of Fertilizer.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Of Calculating Fertilizer On Truck A.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Of Calculating Fertilizer On Truck B.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Of Calculating Fertilizer On Truck C.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Capacity Planning Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Picking List.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Physical Transfer STO Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Process Order Delivery Latter.Queue	0.00	0.00	0.00	0.00	0.00	0.00

Other

Figure 9. Results of average waiting time values with Arena Simulation

These times were calculated over a one-year period during the simulation run. Below are the results of the waiting time analysis from the Arena Simulation.

After analyzing the flow of the urea fertilizer delivery process to Line 3 Warehouse and identifying several activities with waste time, it was determined that there is still waste in the fertilizer delivery process. The waste identified in the Arena Simulation only reflects waste related to certain delivery activities. Therefore, further observation and interviews are needed to gain a more detailed understanding of the waste occurring throughout the entire fertilizer delivery process (Table 2).

Table 2. Waste Identification Table

No	Activity
1	Inappropriate Processing
2	Transportation
3	Waiting
4	Unnecessary Movement
4.A	Loading of fertilizer by the picker onto the truck
4.B	The goods are placed in the unloading area of Warehouse Line 3
5	Over Processing
5.A	The truck inspection before entering the warehouse area.
6	Defect
7	Unnecessary Inventory

In the Unnecessary Movement category, there are two activities identified: the first is the loading of fertilizer onto the truck by the picker, where the process is performed using one person with a forklift to transport the fertilizer into the truck, and two workers are needed to arrange the fertilizer inside the truck. The second activity is the placement of goods at the unloading area of the Line 3 Warehouse, where the unloading of fertilizer from the truck is done manually by 8 workers carrying the fertilizer on their shoulders.

In the Over Processing category, there is a delay in the truck inspection before entering the Warehouse area. During this activity, the truck is weighed, and both the truck and documents are manually inspected.

After determining the types of waste (inefficiencies), the 5W+1H method will be used to analyze the problems and systematically develop improvement proposals.

The primary cause of the waste in the distribution process is the truck inspection before entering the Warehouse area. In this activity, the truck is weighed, and both the truck and documents are manually inspected by one worker. Therefore, the proposed improvement is to create a Monitoring Board to monitor, control, and evaluate the condition of trucks to ensure they are ready for deliveries at any time. This is expected to improve efficiency and reduce the time spent on excessive inspections (Table 3).

Table 3. 5W+1H Truck inspection before entering the Warehouse area

5W+1H	Description
What	Truck inspection before entering the Warehouse area
Why	The truck is weighed, and the truck and documents are manually inspected by one worker.
Who	Inspection Staff
Where	The section responsible for truck inspection
When	At the time the truck enters the Warehouse.
How	Create a Monitoring Board to monitor and evaluate trucks to ensure they are in good condition and ready to accept orders at any time.
References	Nur Taqwanur, 2020. Implementation of Lean Thinking Method to Reduce Non-Value Adding Activities and Improve Performance at PT. XK.

The second main cause of waste in the distribution process is the picker loading fertilizer onto the truck. In this activity, one person uses a forklift to load the fertilizer into the truck, and two workers arrange the fertilizer inside the truck. The proposed improvement is adding one more worker to arrange the fertilizer, which is expected to speed up loading the fertilizer onto the truck (Table 4).

Table 4. 5W+1H Loading of fertilizer by the picker onto the truck

5W+1H	Description
What	Loading of fertilizer by the picker onto the truck
Why	Using 1 person with a forklift to transport the fertilizer into the truck and 2 workers to arrange the fertilizer inside the truck.
Who	Warehouse staff
Where	Loading section in the warehouse
When	During the process of loading fertilizer onto the truck
How	Adding 1 more worker to arrange the fertilizer
References	Abdullah Siddiq, 2021. Proposal for Minimizing Fertilizer Loading Process Queues with Simulation at PT. Petrosida Gresik

Table 5. 5W+1H The goods are placed in the unloading area of Warehouse Line 3

5W+1H	Description
What	The goods are placed in the unloading area of Warehouse Line 3
Why	The fertilizer is manually lifted by 8 workers.
Who	Warehouse staff of Warehouse Line 3.
Where	Unloading section of Warehouse Line 3.
When	During the process of unloading fertilizer in the unloading area of Warehouse Line 3.
How	Use a conveyor belt.
References	Arimad Dwi D, 2015. Analysis of Efficiency on Belt Conveyor to Improve Efficiency in Sugarcane Transport at Kebonagung Sugar Mill.

The third main cause of waste in the distribution process is the placement of goods in the unloading area of Warehouse Line 3. In this activity, the process of unloading fertilizer from the truck is done manually with 8 workers. Therefore, the proposed improvement is to use a conveyor belt as an assistive tool for unloading fertilizer from the truck to the warehouse, which is expected to make the fertilizer placement process more efficient (Table 5).

Based on the proposed improvements, an estimated efficiency per activity is calculated based on references from other journals, resulting

in an estimated time after the improvement. Table 6 shows the efficiency improvement time based on the reference.

After identifying several improvement proposals to enhance the efficiency of the distribution process from Warehouse Line 1 (PT. PIM) to Warehouse Line 3 (Lhokseumawe), these proposals will be simulated using Arena Software. This simulation aims to validate the impact of the improvements on the distribution process by implementing seven optimal scenarios in the Arena Simulation. From these, three scenarios were identified as the best. Table 7 presents the selection of the three best scenarios in the Arena Simulation.

Based on the analysis of all 7 scenarios, the highest average value is found in scenario 6, with a reduction of 36.49%. The analysis shows that reducing all activities does not necessarily lead to an optimal reduction in waiting time due to bottlenecks. If there is a process that becomes a bottleneck or a workstation with limited capacity, it can cause long queues. Although processing times in other activities may be reduced, queues

Table 6. The time efficiency improvements based on the references

Number Activity	Land Route Activities	Current Time (Minutes)	Efficiency Improvement per Activity (Percent)	Time After Improvement (Minutes)
6	Truck inspection before entering the Warehouse area (No.6)	12	9.00%	10.92
8	Loading of fertilizer by the picker onto the truck (No.8)	54	26.00%	39.96
20	The goods are placed in the unloading area of Warehouse Line 3 (No.20)	64	28.80%	45.57

Table 7. Results of the Selection of the 3 Best Scenarios in Arena Simulation

No	Scenario	Land Route Activities	Current Waste Time (Minutes)	Waste Time after Improvement (Minutes)	Waste Reduction (%)	Average (%)
3	Improvement of Land Route Activity no.20	Truck inspection before entering the Warehouse area (No.6)	0.39	0.39	0.00	34.12
		Loading of fertilizer by the picker onto the truck (No.8)	56.91	55.56	2.37	
		The goods are placed in the unloading area of Warehouse Line 3 (No.20)	428.41	0.00	100.00	
6	Improvement of Land Route Activity no.20 and no.6	Truck inspection before entering the Warehouse area (No.6)	0.39	0.35	9.00	36.49
		Loading of fertilizer by the picker onto the truck (No.8)	56.91	56.64	0.47	
		The goods are placed in the unloading area of Warehouse Line 3 (No.20)	428.41	0.00	100.00	
7	Improvement of Land Route Activity no.6,8, and 20	Truck inspection before entering the Warehouse area (No.6)	0.39	0.35	9.83	28.69
		Loading of fertilizer by the picker onto the truck (No.8)	56.91	38.49	32.38	
		The goods are placed in the unloading area of Warehouse Line 3 (No.20)	428.41	240.55	43.85	

at the bottleneck point will add to the waiting time.

The result of the time change after improvements is 323 minutes, with a time difference of 20 minutes from the previous value. This change is achieved by implementing scenario 6, which includes improvements to the activity Truck Inspection Before Entering the Warehouse Area by suggesting the creation of a Monitoring Board for trucks in good condition and ready to accept orders at any time, and changes to the activity Placing Goods on the Unloading Area at Warehouse Lini 3 by suggesting the use of a Conveyor.

IV. CONCLUSION

The conclusion of the research conducted on the distribution process activities from Line 1 Warehouse (PT. PIM) to Line 3 Warehouse (Lhokseumawe) is as follows: The waste identification results revealed two categories of waste: Over Processing and Unnecessary Movement. In the Over Processing category, one wasteful activity was identified: the truck inspection process at the warehouse. The proposed improvement is to implement a monitoring board. In the Unnecessary Movement category, two wasteful activities were identified the loading of fertilizer by pickers and placing it on trucks. The proposed improvement is to add one worker to assist with fertilizer arrangement. The placement of goods in the unloading area of Line 3 Warehouse. The proposed improvement is to use a conveyor belt, which is expected to make the placement process more efficient in the unloading area of Line 3 Warehouse. The analysis of Lean Distribution implementation for urea fertilizer products to minimize waste, conducted using Arena Simulation, concluded that Scenario 6 yielded an average waste reduction of 36.49%. This improvement was achieved by optimizing activities 20 and 6, which provided the best scenario for implementing Lean Distribution. Consequently, the processing time was reduced from 343 minutes to 323 minutes, resulting in a time savings of 20 minutes.

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