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Application of Lean Concept on Replacement Process of Gauze Catalyst at PT Kaltim Nitrate Indonesia

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ABSTRACT

PT KNI is a foreign investment company that produces Ammonium Nitrate (AN), used as a component in explosive raw materials. During the early-stage production process, PT KNI faced the problem of replacing the Gauze Catalyst, which took a long time, causing the machine to experience downtime for 169 hours, or equivalent to a loss of USD 5,874,440. This problem is caused by non-value-added activities (waste) during the catalyst replacement process. Therefore, this study aims to identify waste and recommend corrective actions to reduce or eliminate them. This study adopts the lean approach by applying Process Activity Mapping and Root Cause Analysis (5 whys, Cause and Effect Diagram) to help identify non-value-added/wasteful activities and determine their root causes. The proposed improvements to address the root causes of waste include implementing 5S to make employees work more effectively and efficiently, developing Standard Operating Procedures (SOPs) that are in line with the current situation to facilitate employee work, adopting Vendor Managed Inventory (VMI) to build mutually beneficial business relationships between PT KNI and vendors, providing training to improve employee productivity, and ensuring the availability of tools, group communication, and a more ergonomic work environment. These improvements could eliminate wastage for 478 minutes and save USD 276,921.33 (4.72%) costs, thereby improving company performance.

KEYWORDS: Lean Concept, Process Activity Mapping (PAM), Root Cause Analysis, Vendor Managed Inventory (VMI), Waste Reduction, Scheduled Down Time

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1. INTRODUCTION

PT. Kaltim Nitrate Indonesia (KNI) is a manufacturer of Ammonium Nitrate (AN) with one of the largest capacities in Indonesia (300,000 tons per year). However, according to the production period 2020-2021, PT. KNI can only produce 268,895,700 kg of AN, 89.6% of the total production capacity. It indicates that PT. KNI has not been able to utilize its production capacity fully. The production process goes through several stages in three different plants: the Nitric Acid (NA) Plant, where nitric acid is produced; the Ammonium Nitrate (AN) Plant, used to produce 970mtpd of 100% AN; and the Bagging Plant dedicated to packaging and storing the produced AN prill products. Among these three plants, the NA Plant plays a crucial role. If there are issues in the production process at the NA Plant, the subsequent plants will also face problems. Therefore, this research will focus on the main constraints experienced by PT. KNI in the upstream production (NA Plant).

The operational performance in the upstream production of PT. KNI is measured using the Overall Equipment Effectiveness (OEE) metric. Based on the OEE measurement results from October 2020 to September 2021 (Table 1), this study will focus on the problems in activities related to scheduled downtime. This area accounts for the largest production time loss, amounting to 169 hours (32.6% of the total plant loss), resulting in significant financial losses. If the machines can operate smoothly for 169 hours, the NA Plant can produce 7,436 tons of AN (with an average production of 44 tons per hour). Based on the May 2022, the price of AN per ton is USD 790. By calculating the financial losses due to the plant's non-operation for 169 hours (7,436 tons), PT. KNI incurs a loss of USD 5,874,440 from the catalyst gauze replacement process.

TABLE 1. Measurement of Overall Equipment Effectiveness (OEE) at the NA Plant for Oct 2020 – Sep 2021.

Descriptions	Full Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1.Availability Loss	397 hrs	-	14hrs	-	169 hrs	-	30 hrs	54.4 hrs	0.2 hrs	57.5 hrs	24.7 hrs		47.3 hrs
1.1 Scheduled Down Time	169 hrs	-	-	-	169 hrs	-	-	-	-	-	-	-	-
Problem					7 days Scheduled Replace Gauze								
1.2 Unscheduled Down Time	101 hrs	-	14.0 hrs	-	-	-	30.0 hrs	11.4 hrs	0.2 hrs	9.3 hrs	-	-	36.2 hrs
Problem			trip caused by X12B active suspect module Problem				trip due to instrument Bad data TT12011 due to lightening on big rain	trip at 11/4/2021 due to pump 88P00IC failure	trip due to F112045 process to Absorber low flow due to FIC12024 faulty	trip due to FI12045 Process to Absorber low flaw due to FIC12024 faulty			Shutting down adding catalyst Gauze AND NAP process start up delay due to PV12557 not working properly
1.3 External to Site	127 hrs	-	-	-	-		-	42.9 hrs	-	48.2 hrs	24.7		11.1
Problem								trip due to KDM failure		plant stop due to power turbine failure and steam KDM limited	Plant rate down due to steam KDM limited		shipping delay due to location port full load
1.4 Internal Demand	-	-	-	-	-	-	-	-	-	-	-	-	-
2.Performance (Rate) Loss	122 hrs	-	-	-	4.6 hrs	4.6 hrs	19.9 hrs	18.7 hrs	5.7 hrs	11.8 hrs	18.8 hrs	15.2 hrs	27.6 hrs
3.Quality Loss	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Plant (OEE) Loss	519 hrs		14.0 hrs	-	169.0 hrs	4.6 hrs	49.9 hrs	73.1 hrs	5.9 hrs	69.3 hrs	43.4 hrs	15.2 hrs	74.9 hrs

Implementing lean concepts is considered suitable for addressing the company's problems related to downtime issues (Mostafa et al., 2015). According to (Smith & Hawkins, 2004), lean is a systematic approach to identifying, analyzing, and eliminating waste through proper management. Implementing this concept can provide various benefits, such as reducing the lead time of maintenance activities and improving machine effectiveness (Andarnis, 2011). The essence of this concept lies in maximizing the maintenance process with minimal input, aiming to minimize waste that can result in financial and non-financial losses. Based on the background presented earlier, the research problem to be addressed in this study is how to reduce waste in the catalyst gauze replacement process in the NA Plant and propose improvement recommendations for that process using lean concepts.

2. LITERATURE REVIEW

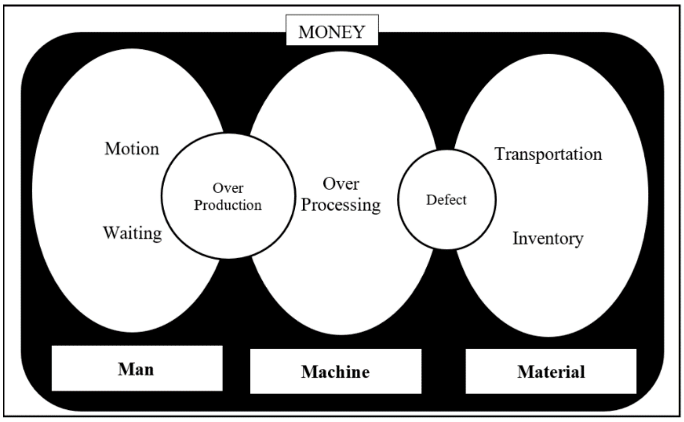
Lean Concept

The lean concept comprises five main elements: manufacturing flow, organization, process control, metrics, and logistics (Feld, 2001). Manufacturing flow focuses on implementing physical changes and standard designs in operational processes. The organization emphasizes identifying roles and functions within the system. Process control involves monitoring, controlling, stabilizing, and seeking process improvements. Metrics are used to measure performance and outcomes. Logistics provides operational rules and mechanisms for planning and controlling material flow.

Furthermore, (Dennis, 2007) and (Gupta & Jain, 2013) have formulated four key stages for implementing the lean concept. Firstly, identifying existing waste in the system. Secondly, identifying waste in various operational processes. Thirdly, seeking solutions for the sources or root causes of waste. Fourthly, planning the implementation process by testing recommended improvements obtained beforehand.

Waste

Waste refers to non-value-added activities that customers are not willing to pay for. According to (Gaspersz, 2007), waste encompasses activities that do not provide value throughout a company's operational value chain. Efficient execution of operational processes, such as production, machine maintenance, and services, is essential to minimize costs and time, maximize profitability, and reduce waste. Therefore, a comprehensive understanding of the company's operational system is necessary to avoid non-value-added activities.



Source: (Rawabdeh, 2005)

FIGURE 1. The Basic Model of the Relationship between Waste

In the lean concept, Taiichi Ohno of the Toyota Production System (TPS) classified waste into seven types (TIMWOOD): Transportation, Inventory, Motion, Waiting, Overproduction, Over Processing, and Defects. According to (Rawabdeh, 2005), all types of waste can influence one another mutually. It means that they not only affect other types of waste but are simultaneously affected by them. Furthermore, (Rawabdeh, 2005) developed a basic model that categorizes and interrelates waste based on its relationship with humans, machines, and materials. The diagram below illustrates the interrelation between human, machine, and material.

Lean Tools

When implementing the lean process, companies' main challenge is selecting the appropriate lean tools for specific problems. According to (Aucasime-Gonzales et al., 2020), many companies choose analysis tools that may not align with their problems. It can result in missed opportunities to achieve maximum efficiency and provide recommended solutions. Therefore, researchers and practitioners must carefully consider and align the company's problems with the appropriate analysis tools.

Numerous lean analysis tools can be applied in a company's business operations to support performance improvement. Each tool is highly interrelated and complements others to identify, reduce, or eliminate waste from processes, leading to sustainable improvements. However, there are also stand-alone tools that address specific business problems. Various literature explains that companies can adopt many lean analysis tools to enhance their performance.

Process Activity Mapping (PAM)

PAM is an analytical tool that describes the production process in detail by outlining each activity that occurs throughout the process. According to (Hines & Rich, 1997), PAM maps waste at a high level of correlation and usefulness. PAM can break down activities into complex levels with multi-level operation charts, providing an overall understanding. Additionally, PAM applies to various industries and processes (Korchagin et al., 2019), making it a more powerful analysis tool than value stream mapping (Dinis-Carvalho et al., 2015).

Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is an analysis tool used to explain the causes and effects of problems and identify factors that significantly impact the working system. According to (Rooney & Vanden Hauvel, 2004), RCA is a logical framework that eliminates the root causes of unwanted problems. By implementing corrective actions on the "root causes," RCA ensures the elimination of identified problems. A commonly used approach in RCA is the 5 Whys analysis method, involving multiple iterations of asking "why" until the fundamental problem is identified. However, (Pylipow & Royall, 2001) suggest that the questioning can be discontinued if researchers no longer require additional answers to find the root cause. In addition, cause and effect diagrams are commonly used to find problem sources. Researchers utilize the 4M + 1E method, considering man, machine, material, method, and environment. Cause and effect diagrams are prevalent in lean research as they simplify the work environment by reducing waste and non-value-added activities like the inability to locate necessary tools or documents.

Vendor Managed Inventory (VMI)

Introduced in the early 1980s, Vendor Managed Inventory (VMI) is a flexible business concept in which suppliers are responsible for replenishing inventory based on customer-provided data or information. VMI aims to improve and streamline the core order fulfillment process (Beheshti et al., 2020). Collaborative processes among supply chain partners can reduce lead time and operational costs by minimizing the risk of demand amplification (bullwhip effect) (Claassen et al., 2008; Disney et al., 2004; Reiner & Trcka, 2004). Implementing the VMI system offers numerous benefits to companies in stock management. VMI ensures accurate records, good condition, and organized availability of all items sold. Additionally, VMI facilitates appropriate stock adjustments, enhancing profitability through improved availability.

Spaghetti Diagram

The spaghetti diagram visually represents the continuous flow lines tracing the path of items or activities through a process. It is also known as a spaghetti chart, spaghetti model, or spaghetti plot. According to (Kanaganayagam et al., 2015), this analysis tool observes object movement within a system using lines. Through the analysis, researchers determine the length, quantity, and overlapping movements (redundancy). Implementing the results of the spaghetti diagram helps identify inefficient movements and ineffective areas, reduce staff, and make organizational or workstation layout changes to enhance productivity.

Impact Effort Matrix

The Impact Effort Matrix is a tool designed to prioritize proposed recommendations. According to (Seibert, 2012), this matrix helps researchers assess and select potential solutions based on the relative impact and effort required. Previous studies, such as (Oliver et al., 2019), (Gomes Leite et al., 2018), and (Ghiyasinasab et al., 2022), have used this method as an analysis tool compatible with the implementation of the lean concept. The matrix consists of four quadrants. First, "quick wins" represent decision recommendations that provide the best benefits with minimal effort in solving a problem or activity. Second, "major projects" are recommendations that can significantly impact but require a substantial investment of time or cost from the company. Third, "fill-ins" are recommendations that require minimal effort but have a small impact on outcomes. Fourth, "thankless tasks" are high-impact recommendations that require substantial effort.

3. METHODS

The methodology used in this study is described in detail. In general, the study uses four steps, as shown in Figure 2: identifying waste, identifying sources of waste, determining improvement recommendations, planning implementation and managerial implications.

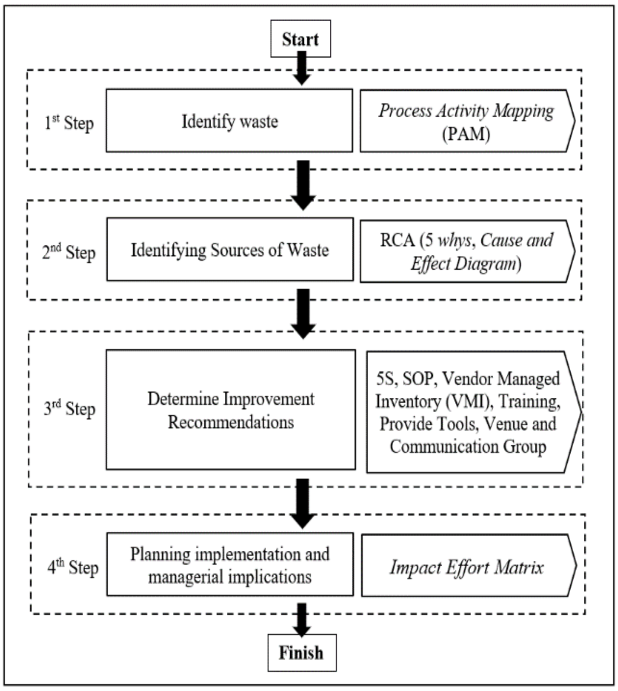


FIGURE 2. Stages of Research Methods.

4. RESULTS

Identifying Waste

Process Activity Mapping (PAM) is used to help researchers map all the activities involved in the gauze catalyst replacement process, classify the activities, and identify waste types. When creating the PAM, the researcher utilized historical data from the gauze catalyst replacement process in 2021. This data was subsequently verified through direct observation and interviews with employees responsible for the related activities. These steps were taken to ensure the validity of the generated data.

TABLE 2. Recapitulation of Process Activity Mapping (PAM) of Gauze Catalyst Replacement

Activity	Total Activity	Activity Percentage	Time (Minute)			
			VA	NNVA	NVA	Total
Operation	42	55%	4405	0	170	4575
Transportation	9	12%	310	30	0	340
Inspection	17	22%	80	0	315	395
Storage	0	0%	0	0	0	0
Delay	9	12%	0	0	1335	1335
Total	77	100%	4795	30	1820	6645
Percentage			72.16%	0.45%	27.39%	100%

Based on the summary of the PAM in the gauze catalyst replacement process (Table 2), the majority percentage consists of value-added activities, accounting for 72.16%, with a total duration of 4,795 minutes. The breakdown of activities is as follows: 4,405 minutes for Operations, 310 minutes for Transportation, and 80 minutes for Inspection.

Additionally, non-value-added activities that are necessary (NNVA) have a total duration of 30 minutes or 0.45% of the total. Lastly, non-value-added activities (NVA) amount to 1,820 minutes (27.39% of the total activity breakdown). The activity types include Operation (170 minutes), Inspection (315 minutes), and Delay (1,335 minutes). Table 4.4 provides explanations for classifying non-value-added activities (NVA).

TABLE 3. Weste Identification

Type of Waste	Waste Identified
Waiting	9
Overprocessing	15
Motion	1
Total Waste	25

Based on the waste identification results in Table 3, it is found that there are 25 activities indicating waste in the gauze catalyst replacement process. These wasteful activities consume a total of 1,820 minutes or 30.3 hours. The most identified type of waste is Overprocessing, with 15 activities. This waste occurs due to unnecessary work processes in adding value, such as repetitive activities, activities requiring approval (e.g., checks and discussions), and cleaning activities. Waiting is indicated as waste in 9 activities. Waiting is claimed to be a waste due to idle time in the work process. Lastly, there is 1 activity indicating Motion waste. It is caused by the activity not adhering to ergonomic principles (safe, healthy, comfortable, effective, and efficient), resulting in decreased employee productivity.

Identifying Sources of Waste

The search for waste sources is conducted using the RCA method with 5 Whys and root cause diagrams (4M + 1E). Data is collected through direct observation and interviews with employees directly involved. The final results of waste source identification in the gauze catalyst replacement process can be seen in Table 4.

TABLE 4. Cause Identification

Root Cause	Cause Identified
Machine	3
Method	11
Man	10
Material	4
Environment	4
Total Cause	32

Determining Improvement Recommendations

The researcher utilizes analysis tools such as 5S to enhance employee effectiveness and efficiency, develops Standard Operating Procedures (SOP) suitable for the current situation to facilitate employees' work, and adopts Vendor Managed Inventory (VMI) to establish mutually beneficial business relationships between PT. KNI and vendors provide training to enhance employee productivity and ensure the availability of tools, group communication, and a more ergonomic work environment. For more detailed results, refer to the Tabel 4.

TABLE 5. Recapitulation of Recommendations for Improvement

No.	Action Plan	Time		
		Before	After	Efficiency
1	Provide early scaffolding as needed	60	10	50
2	Updating SOP with like factory reference can be accessed at 180'C	535	458	77
3	Updating the method in the Work SOP in the form of injecting condensate repeatedly	535	458	77
4	Updating the SOP by changing the purging method	140	96	44
5	Updating SOPs to be adaptive to current issues	30	20	10
6	Create an organizational structure according to the job description	18	7	11
7	Updating SOPs to be adaptive to current issues	5	0	5
8	Perform routine and scheduled calibration of scales	10	0	10
9	Updating SOPs to be adaptive to current issues	6	5	1
10	Create an organizational structure according to the job description	10	0	10
11	Create an organizational structure according to the job description	8	6	2
12	Coordinate between vendors and PT. KNI regarding the technical process of its implementation via Vendor Managed Inventory (VMI)	20	5	15
13	Coordinate between vendors and PT. KNI regarding the technical process of its implementation via Vendor Managed Inventory (VMI)	12	5	7
14	Coordinate between vendors and PT. KNI regarding the technical process of its implementation via Vendor Managed Inventory (VMI)	12	5	7
15	Coordinate between vendors and PT. KNI regarding the technical process of its implementation via Vendor Managed Inventory (VMI)	11	5	6
16	Open Tender or procurement via Vendor Managed Inventory (VMI)	10	5	5
17	Operator training	50	40	10
18	Operator training	4	0	4
19	Operator training	10	4	6
20	Provide a document list of items that will be used earlier	11	0	11
21	Provides a visual board regarding activity restrictions other than related activities.	7	0	7
22	Provides a visual board regarding activity restrictions other than related activities.	15	0	15

No.	Action Plan	Time		
		Before	After	Efficiency
23	Provide radio communication to the staff responsible for the activity to inform them when it will be completed.	30	20	10
24	Provide radio communication to the staff responsible for the activity	30	20	10
25	Provide radio communication to the staff responsible for the activity	10	8	2
26	Provide blowers; activities are carried out at night	10	0	10
27	Provide handling equipment following the nature of the work	9	0	9
28	Provide tools appropriate to the nature of the work	2	0	2
29	Contact and pick up the Customs team ahead of the execution	30	21	9
30	Contact and pick up the Customs team ahead of the execution	30	21	9
31	Coordinate with the warehouse department staff to be prepared immediately.	30	10	20
32	Provide a safe and comfortable place	60	30	30

Planning Implementation and Managerial Implications

The Impact-Effort Matrix is specifically used to prioritize various proposed improvement recommendations. In this study, the impact is based on the efficiency gained in terms of time. In contrast, effort is based on the required effort (human resources, duration of improvement, and risk) to implement the recommended solutions. Figure 5.3 shows the four quadrants of the impact-effort matrix. For more detailed results, refer to the Figure 3.

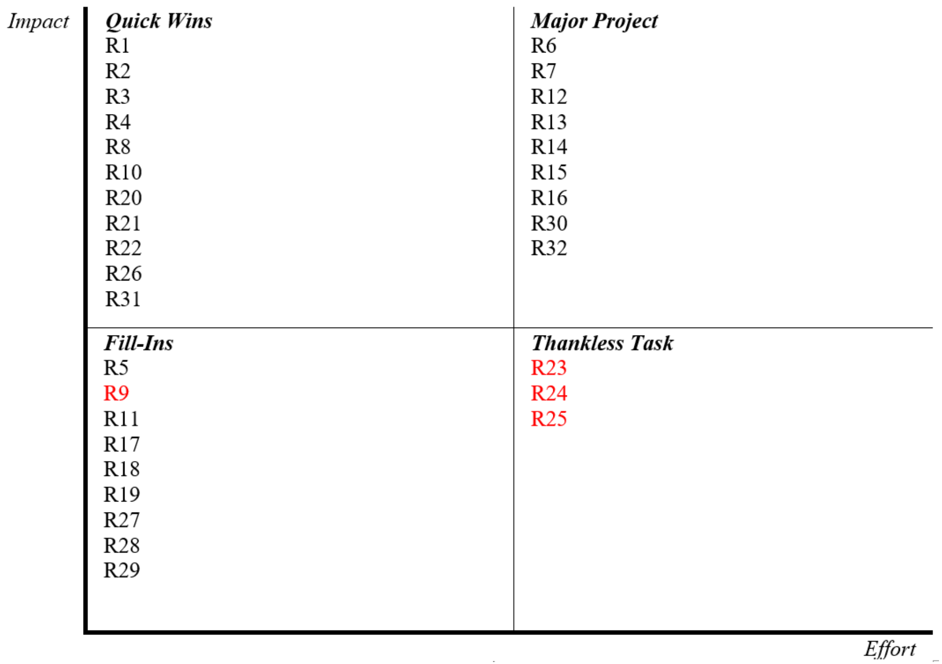


FIGURE 3. Impact-Effort Matrix

Managerial implications refer to the impact generated by the involvement of various management components within an organization, such as resources, policies, and specific activities. To determine the priority of solutions, the researcher used the Impact-Effort Matrix approach, which encompasses various improvement recommendation projects. The researcher excluded recommendations 9, 23, 24, and 25 due to their low impact on improvement but high requirements in terms of time, effort, and cost.

5. CONCLUSIONS

The gauze catalyst replacement process has 25 non-value-added activities (waste). The most common type of waste identified is overprocessing with 15 activities. Waiting accounts for 9 activities, and motion accounts for 1 activity. Out of the 25 non-value-added activities (waste), the researcher identified 32 root causes of waste. These root causes stem from method issues with 11 cases, man with 10 cases, environment with 4 cases, material with 4 cases, and machine with 3 cases. The researcher recommends implementing 5S to make employees work more effectively and efficiently, creating Standard Operating Procedures (SOP) that align with current operational standards to facilitate employees' work, and adopting Vendor Managed Inventory (VMI) to establish mutually beneficial business relationships between PT. KNI and vendors, providing training to enhance employee productivity and ensuring the availability of tools, group communication, and a more ergonomic work environment. By utilizing the impact-effort matrix analysis, the proposed improvement measures can potentially enhance company performance by eliminating waste for 478 minutes and estimated cost savings of USD 27,6921.33 (4.72%).

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