The Analysis of Lean Manufacturing in Waste Reduction During Rosin Ester Production at PT XYZ

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Abstract

Waste are commonly generated during the utilization of raw materials. Therefore, they are become important to consider lean manufacturing to achieve the overall business objectives. PT XYZ is a major company in processing pine resin and its derivatives, including gum rosin, turpentine and rosin ester, mainly used as featured commodities. During production, a certain amount of unwanted materials in the form of defect and in the form of work-in-process (WIP) that caused waiting wastes are obtained, particularly at the rosin ester floor. This study aims to identify the waste types and their dominant factors that caused waste occurred in PT XYZ, as well as recommend improvement strategies in boosting production efficiency. Based on the identification results, two dominant wastes occurred in the form of defects and waiting. The defect and scrap portions were prevalent in gum rosin drops, flakes, brushed dust and products that did not fulfill color and size specifications at 63.72 kg/shift that equal to 2,08% scrap rate per shift. Meanwhile, waiting waste refers to work-in-process (WIP) on Oleo Pine Resin (OPR) storage and delay interval for a complete sampling process. The WIP circumstance was also observed at the packaging workstation. Furthermore, repairing tank leaks, allocating special workers to flaking workstations, extending workers' supervision, combining flake cooling and transportation processes, procuring cooling conveyors and increasing the quantity of esterification reactors were recommendations for optimum production. These proposed activities have the capacity to enhance the process cycle efficiency (PCE) value from 4.65 to 6.34%.

Keywords: *Rosin Ester, Value Stream Analysis Tools, Value Stream Mapping, Waste*

1. INTRODUCTION

Pine resin and its derivatives are among the non-timber forest commodities potentially developed in Indonesia. These materials exist in the form of gum rosin, turpentine, and their derivatives, including rosin esters. Rosin ester is a pale-yellow derivative of gum rosin and also occurs in the form of flakes. In addition, the sample is synthesized by an abiotic acid esterification process involving certain additives, such as *pentaerythritol* and *glycerin*.

PT XYZ is focused on the production of processed pine resin and its derivatives. In fulfilling consumer demands, certain production challenges tend to occur, particularly waste generation.

A previous study defined waste as the overall activities without any value to both the production process and the final commodities (Hines and Rich, 1997). The lean manufacturing concept identifies seven waste of lean, including overproduction, defects (defective products), waiting, excessive transportation, inappropriate processing, as well as unnecessary inventory and excessive motion. Based on this classification, two waste categories were reported in PT XYZ, including waiting and defects. In terms of waiting waste, materials are delayed while other subsequent processes are completed, but defects refer to several scraps present in drop-like forms of gum rosin, flakes and sweeping dust. Considerable losses are however observed in both waste types, with respect to time and cost. Therefore, a feasible method is highly needed in minimizing waste generation.

Lean manufacturing is an important approach in waste reduction. This concept refers to a set of systems in identifying and eliminating waste, improving output quality, as well as declining production costs and time (Wilson, 2010). In practice, several tools are employed in waste detection, including value

stream mapping (VSM), value stream analysis tools (VALSAT) and the waste assessment model (WAM). Also, the process cycle efficiency (PCE) value is calculated as a percentage of the time interval in adding product value, compared to the total process duration (Nugroho et al., 2015). Analysis results related to dominant waste detection are considered during the formation of improvement recommendations. Therefore, this study aims to identify the waste types and their dominant factors in PT XYZ, as well as propose improvement strategies in minimizing waste and increasing production efficiency.

2. MATERIAL AND METHODS

2.1 Approach
This study was conducted at PT XYZ which is located in Java Island, specifically in the production process of rosin ester from February-April 2021. Two stages were involved where the first encompassed data collection and the second is data processing.

2.2 Data Collection
Data collection was carried out in three ways, either by direct observation, using a stopwatch, and by distributing questionnaires. The relevant data included processing time, total raw materials, production data, product demand, waste quantity, production process flows, as well as the distance and flow of material transfer. Purposive sampling questionnaire was also distributed, particularly to production experts. This document existed in the form of a waste assessment questionnaire (WAQ) to identify and map the production floor wastes (Rawabdeh, 2005).

2.3 Data Processing
2.3.1 Current State Mapping
The current state map between the flow of information and materials was plotted comprehensively. Furthermore, the useful data for the current state map was calculated as follows:

1. Cycle time (Ws) evaluation, using the formula:

$$Ws = \frac{\sum_{i=N}^{n} xi}{N} \qquad (1)$$

xi = Process time
N = Total amount of data

2. Normal time (Wn) and standard time (Wb)

calculation with the formula:

$$Wn = Ws \times (1 + Rating\ Factor) \qquad (2)$$

$$Wb = Wn \times \frac{100\%}{100\% - \%allowance} \qquad (3)$$

3. Takt time determination, which represents the rhythm/production rate using the formula:

$$Takt\ time = \frac{Available\ time}{Product\ Demand\ per\ Day} \qquad (4)$$

4. Lead time inventory (LTI) estimation, which refers to the material wait duration, using the formula:

$$LTI = \frac{Inventory}{Production\ rate} \qquad (5)$$

5. Process lead time (PLT) evaluation by considering the value-added time (VAT), non-value added time (NVAT), necessary but non-value-added time (NNVAT) and lead time (LT) previously classified and calculated.

$$PLT = VAT + NVAT + LT \qquad (6)$$

6. Process cycle efficiency (PCE) assessment using the formula:

$$PCE = \frac{VAT}{Process\ Lead\ Time} \qquad (7)$$

7. Current state mapping, which represents the flow of information and material, by entering the earlier calculated data and considering the production flow, as well as the flow and distance of material transfer.

2.3.2 Waste Identification
Waste identification was conducted using the resulting data after the current state mapping. The waste assessment model (WAM) serves as a viable method in waste detection, comprising two components, including WAQ and waste relationship matrix (WRM). The first step involves the distribution of WAQ to mainly production experts, including the Head of Factory, Planning and Development Supervisor, and QC Supervisor. This is followed by analyzing the survey results to generate the WRM. Subsequently, the WRM outcomes are used as inputs in VALSAT to determine the waste minimizing tools.

2.3.3 Identification of The Dominant Waste Causes
The causes of dominant waste type from the WAM and VALSAT techniques, were identified using the Fishbone Diagram. This analysis involves brainstorming with relevant stakeholders to generate accurate and comprehensive results. The relevant stakeholders involved include the Production

Manager, QC Supervisor, and Planning and Development Supervisor.

2.3.4 Formulation of Improvement Recommendations and Future State Map Making

The improvement recommendations were formulated after identifying the dominant waste causes. These recommendations serve as inputs in compiling a Future State Map that plots improvement points during production. Subsequently, the initial PCE value is compared with the final results, where an increase is anticipated in the production efficiency.

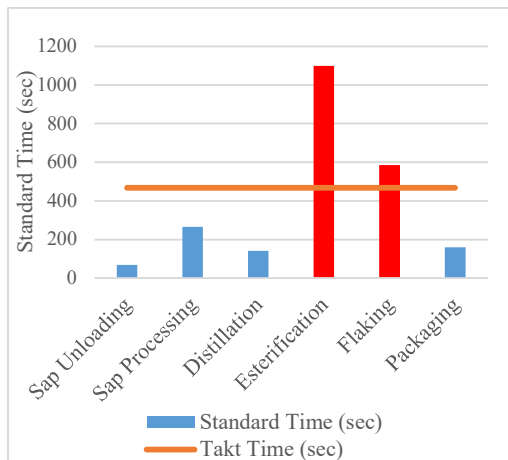## 3. RESULT AND DISCUSSION

3.1 Takt Time

Figure 1. Comparison of Takt Time with Standard Time

PT XYZ operates 6 days a week, with a production interval of 21 hours or 75,600 seconds per day in 3 shifts. The average product demand is estimated at 4,038.46 kg/day or 162 sacks/day.

Formula (4) is used to obtain the takt time at 468 seconds. This indicates the company's capacity in generating 1 sack of product within the rate (Hasanah et al., 2020). The value is then compared with the standard time at each terminal. Two workstations, termed esterification and flaking, reported an extensive standard time, compared to the takt value. However, the processing time in both floors appeared inefficient.

3.2 Process Lead Time

The process lead time (PLT) is estimated by calculating and classifying VAT, NVAT, NNVAT and lead time values, using formula (6) obtained by direct measurement with a stopwatch. Table 1 represents the PLT value.

Table 1. PLT Measurement

Workstation	VAT (sec/pcs)	NVAT (sec/pcs)	NNVAT (sec/pcs)	Lead Time (sec/pcs)
Sap Unloading	48.81	0	20.78	0
Sap Processing	110.74	27.24	43.45	3,473.46
Distillation	82.69	16.20	52.29	6,562.66
Esterification	893.79	32.23	193.36	4,922
Flaking	432.73	0	137.07	0
Packaging	159.57	240	0	19,698.79
TOTAL	1,728.32	315.67	446.95	34,656.91
Process Lead Time				**37,147.84**

Table 1 also obtains the total VAT, NVAT, NNVAT and lead time values at 1,728.32, 315.67, 446.95 and 34,656.91 seconds, respectively. Therefore, the PLT value is 37,147.84 seconds.

3.3 PCE Value

Based on the PLT from previous calculation, the initial PCE was obtained at 4.65 % using formula (7). This value indicates less efficiency, due to minimal VAT percentage, compared to other results that do not contribute to the production process. In comparison to the standard PCE for the fabrication type, the typical and world class cycle efficiency values were 10% and 25%, respectively. This shows the need for improvements to increase the PCE value, at least up to 10% typical cycle efficiency (Gasperz, 2007).

3.4 Developing a Current State Map

The current state map plans the flow of the material and information during the production process (Lee et al., 2007). In addition, its relevant data include the product information and demand, both monthly and daily, takt time value, production interval, number of working days, material flow and information transfer,

processing time, amount of processed materials and the resulting wastes, such as work-in-process (WIP) and product defects/scrap. This approach can also facilitate the design of

improvements to the waste that occurs (Aprilia et al., 2018). Figure 2 represents the current state map in this study.
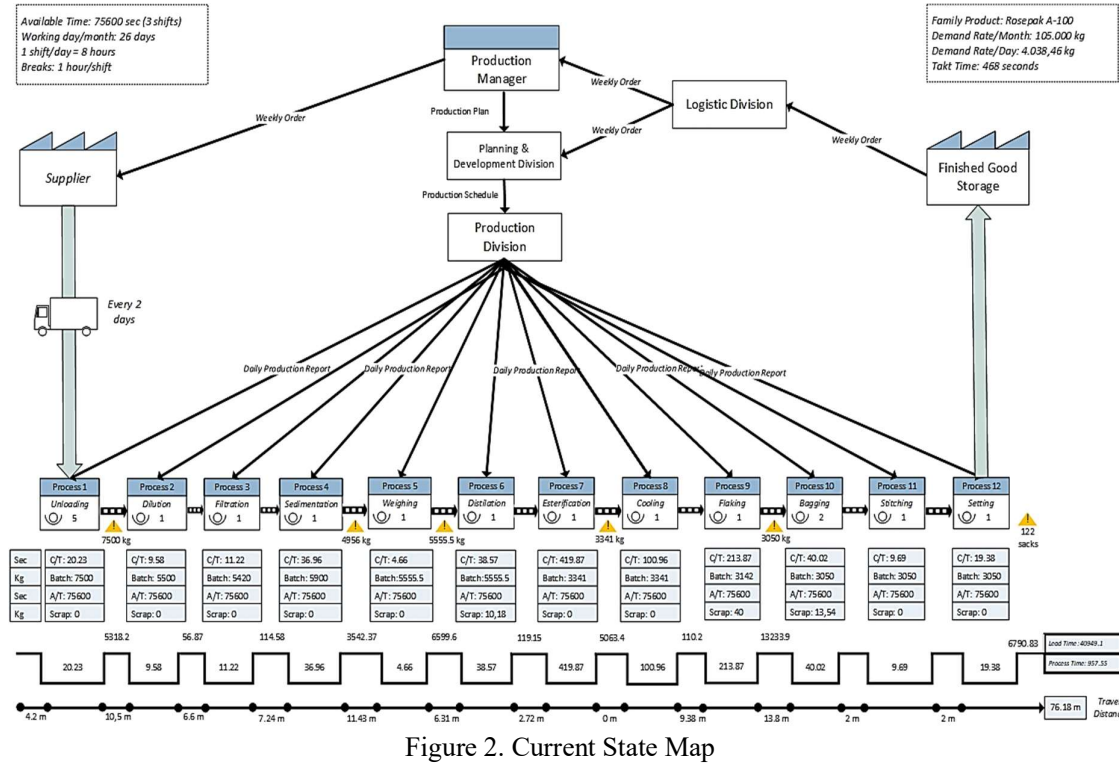

Figure 2. Current State Map

3.5 Waste Identification

Based on the current state map, five WIP wastes in the workstations between settling and weighing, weighing and distillation, esterification and cooling, flaking and bagging, as well as the workstations after pallet stacking amounted to 4,956; 5,555.5; 3,341; 2,892 and 3,050 kg, respectively. Several wastes in the form of scraps were also observed in the information box column, including distillation, flaking and bagging workstations at 10.18, 40 and 13.54 kg, correspondingly.

Apart from observing the current state map in Figure 2, waste identification was also performed using the WAM method. The survey responses were then processed and mapped into the waste matrix value after WAQ distribution and the results represented in Figure 4. Defect and waiting wastes were obtained at 20.32% and 16.97%, respectively, and are possibly minimized, using several VALSAT mapping tools. The result of waste

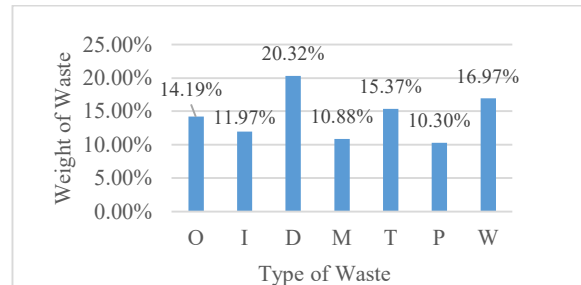identification using WAM method are showed in Figure 3.

Figure 3. Graph of Waste Ranking Results

Furthermore, each WAM weight for the two dominant waste types subsequently served as inputs in determining the suitable mapping tool for improvements. These instruments in the form of process activity mapping (PAM) and supply chain response matrix (SCRM) tend to minimize the waste. Figure 4 represents the weight mapping results in the VALSAT table.
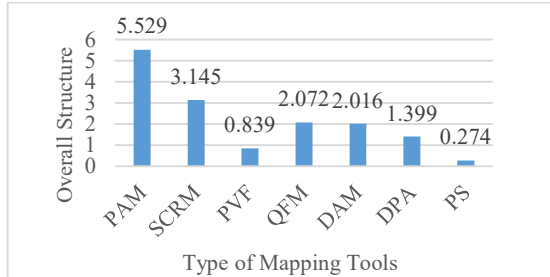
504

Figure 4. Mapping Tools Ranking Results

Based on the PAM tool, the processing time and the number of activities were mapped for each activity type, comprising operations as VA, transportation and inspection as NNVA and storage, in addition to delays as NVA. Figure 5 & 6 show the mapping and classification results of PAM activity types.
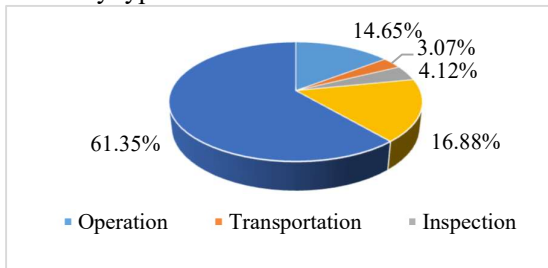

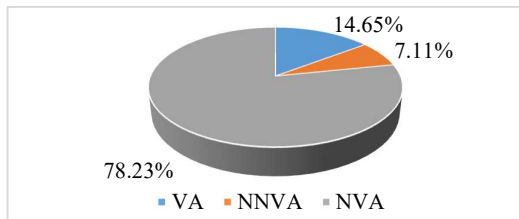Figure 5. Results of Activity Mapping Using PAM

Figure 6. Classification Results by Activity Type

Figure 6 confirms the most dominant activity as non-value added (NVA) at 78.23%; followed by value added (VA) and necessary but non-value added (NNVA) at 14.65 and 7.11%, respectively. This shows a less efficient production process, due to greater NVA in comparison to VA. Therefore, certain NVA activities require urgent waste minimization.

The SCRM mapping tool in VALSAT is used to plot the relationship between inventory and lead time in the production chain. As a consequence, the inventory level required to fulfill consumer demands with the total available lead time is possibly determined. Figure 7 represents the SCRM mapping results.
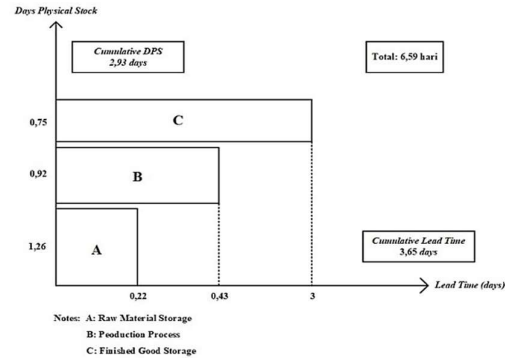

Figure 7. SCRM Mapping Results

Figure 7 also shows the day's physical stock (DPS) or the average material time at each point. The DPS value in the raw material storage, production process and the finished product storage were 1.26, 0.92 and 0.75 days, respectively, with a cumulative DPS value of 2.93. Meanwhile, the lead time values or the material waiting time were 0.22, 0.43 and 3 days, correspondingly. The cumulative lead time value was 3.65 days, while the total SCRM value was estimated at 6.59 days. This shows the finished product warehouse with the most extensive material waiting time, where the commodities with a 3 days waiting period before the products will be delivered. This aims to achieve shipping cost efficiency.

3.6 Analysis of Waste Causes

Waste causes in this study were analyzed using the Fishbone Diagram. Fishbone diagram is a diagram that illustrates the cause of the emergence of an effect (Heizer and Render, 2009). Defects waste, among others, mainly occurred at the distillation, flaking and bagging workstations. These incidents are generally triggered by the machine factor, including a distillation reactor tank leak and unfiltered dirt contamination, as well as human involvement in the form of poor workers' supervision and discipline.

Waiting wastes appeared common in the rosin ester production process, among others, such as OPR storage, weighing work stations, after esterification and packaging work stations. These types are generally caused by

the emergence of WIP material at certain points on the production floor, due to human factor as workers are required to wait for the complete sampling process. The method factor also influenced the delay, due to the inefficient process flow, and the need for the materials to wait after completion. Meanwhile, the machine factor was attributed to its limited capacity, where the flakes cooling process currently employs the manual method with a fan, which takes 20 minutes per 10 sacks.

3.7 Improvement Recommendations
3.7.1 Defect Waste

Improvement recommendations on waste defects encompassed tank leak repairs to the removal of scraps in the form of gum rosin droplets, allocation of special workers to flaking workstations and the increase in worker supervision during scrap removal at the flaking and bagging workstations in the form of flakes, sweeping dust and products that do not fulfill specifications.

3.7.2 Waiting Waste

Improvement recommendations on waiting waste involved combining the flake's cooling and transportation processes. This eliminate WIP and waiting time that previously had to delay for the complete cooling process, by procuring a cooling conveyor. The flakes were subsequently transported through this channel for the cooling process, leading to lead time efficiency. Furthermore, the increase in the number of esterification reactors served as another improvement recommendation. This is considered to eliminate the waiting time for materials to be processed in subsequent stages. Making Future State Map and PCE Calculation after Improvement

The improvement recommendations tend to alter the original conditions already plotted in the current state map. The first change refers to WIP waste at the OPR storage point previously attained at 4,956 kg and in the cooling process, with the removal of flakes earlier obtained at 3,050 kg. In addition, the lead time inventory at these points with intervals of 3,473.46 and 19,698.79 seconds, respectively, were also eliminated. The second difference refers to the ability to remove a scrap of gum rosin droplets which previously amounted to 10.18 kg per batch and 40 kg flake lumps. During esterification and flaking processes, the standard time with initial rate of 893.79 and 432.73 seconds, was reduced after improvements to 297.93 and 189.93 seconds, respectively, while the PCE value originally at 4.65%, increased to 6.34%. Figure 8 represents the future state map in a broader perspective
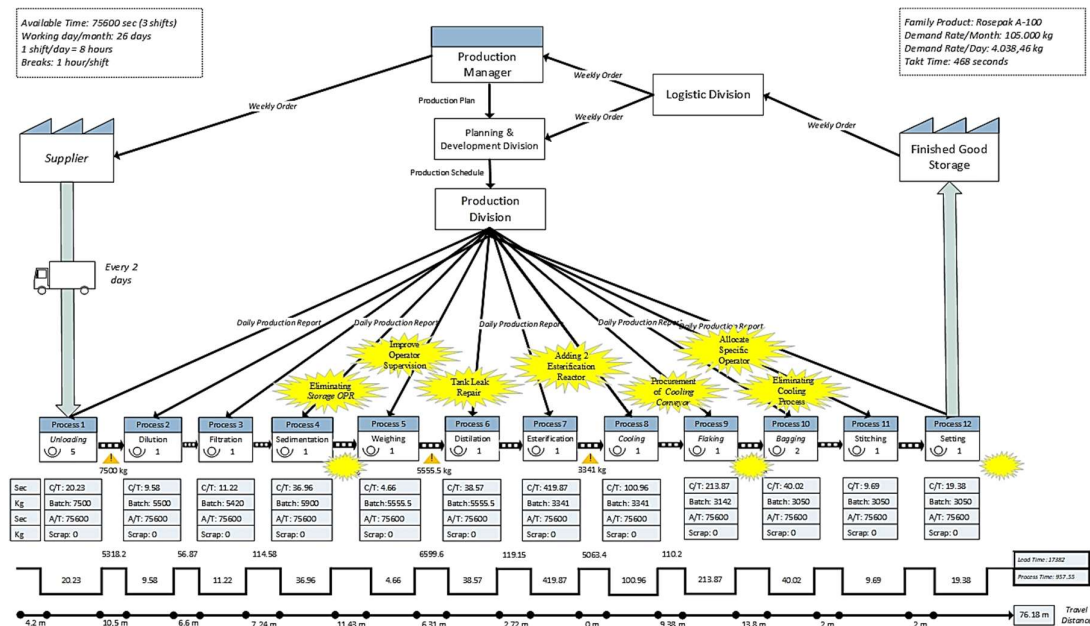

Figure 8. Future State Map

4. CONCLUSIONS

Based on the overall results and discussion, certain conclusions were obtained as follows:

1. The wastes identified in the rosin ester production process included defects in drop-like forms of gum rosin, flakes that do not match color and size specifications, as well as swept dust. However, the waiting wastes in the form of WIP resulted in delays at several points.

2. Factors that caused waste were generally attributed to human, machine and the applied method.

3. The improvement recommendations for waste minimization encompassed the repairs of the distillation reactor tank leaks, allocation of special operators to flaking workstations, increase in workers' supervision, elimination of flake cooling process in the collecting funnel, OPR storage removal, procurement of cooling conveyors and the increase in the quantity of esterification reactors.

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