Planning for Improvement of Carton Box Production Process using Lean Manufacturing Approach to Increase Production Results at PT. Kati Kartika Murni

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Abstract—PT. Kati Kartika Murni is a company engaged in the packaging industry. This company applies a make to order (MTO) system. Carton Boxes are the focus of research because it have the highest number of requests by 55%. Problems faced by PT. Kati Kartika Murni namely the number of customer requests not yet met. This research was conducted to increase the production of carton boxes to 3600 boxes. Increasing the amount of production is done by lean manufacturing approach, namely by identifying waste and eliminating existing waste. Manufacturing lead time before repair is 17811.7 seconds, process cycle efficiency before repair is 44.4489%, and takt time is 4.645 seconds. The number of production before the design of repairs is 3379 boxes, where orders have not been fulfilled with the available time. The highest waste based on the waste assessment model and value stream analysis tools are defect and transportation. The analysis was conducted using the Failure Mode and Effect Analysis (FMEA) method to determine the type of waste that needs to be eliminated. The highest RPN of 448 is the faded color defect in the flexo process and the second highest RPN of 392 is the overlap defect in the corrugating process. Waste transportation analysis using FMEA method shows the highest RPN value of 448, namely at the time of operation and material movement on the production floor. The design of improvements to eliminate waste transportation is to add a roller conveyor functioning as material handling between work stations. One piece flow addition for the corrugating process to flexo. After an improvement plan is made, the Manufacturing lead time is 15634.2 seconds and the Process cycle efficiency is 50.64%. The amount of production after the design improvement is 3850 boxes, where orders have been fulfilled with the available time.

Kata kunci—: Carton Box, Lean Manufacturing, MLT, WAM, VALSAT, FMEA

I. INTRODUCTION

A. Background Problems

PT. Kati Kartika Murni often have problems on the production floor. Based on the results of interviews and research conducted, there are still wastes which do not have add value to the carton box production floor and might be detrimental to the company. Carton Boxes are the focus of research because it have the highest number of requests. In adjusting production results to customer demand and the production process to run smoothly, it is necessary to optimize the carton box production process that is very useful in increasing the efficiency and effectiveness of the production process.

Lean manufacturing is a concept to minimize waste that is considered to be able to overcome problems in increasing effectiveness and efficiency to achieve high productivity on the production floor. Existing waste can be minimized by minimizing set-up time, achieving zero defects, achieving zero inventory, and implementing an effective factory layout. Lean manufacturing can be defined as an approach to identify and eliminate waste or non-value added work elements through radical continuous improvement. Based on this background, it is expected that the Waste Assessment Model (WAM) analysis and lean manufacturing approach using Value Stream Analysis Tools is an effective way to solve problems and optimize performance of PT. Kati Kartika Murni

B. Research Objectives

Based on the formulation of the problem, the purpose of this study is to improve the production of carton boxes using a lean manufacturing approach.

C. Problem Limits

In order for the research to be more focused and not widespread to achieve the research objectives, the following problem limitations are determined:

1) The product under study is a Carton box.
2) Historical data used are production data from November 2018 to February 2019.
3) This research does not pay attention to the cost aspect.
4) It is assumed that the raw material for Carton box products in the form of paper roll is always available.
II. LIBRARY OVERVIEW

A. Lean Manufacturing

Lean manufacturing is a way of thinking, philosophy, methods and management strategies to improve efficiency in manufacturing or production lines. The main objective of Lean Manufacturing is to maximize value for customers and increase company profitability by eliminating Work Elements that do not provide added value (waste).[1]

B. Seven Waste

The focus of lean manufacturing is to eliminate the waste that is found in the production flow. Waste is defined as any activity that uses resources that do not add value to a product. There are seven types of waste, namely Overproduction, Waiting, Transportation, Overprocessing, Inventory, Unnecessary motion, and Defects.[2]

C. Value Stream Mapping (VSM)

Value stream is a map that illustrates all the steps in the work process (including rework) related to the conversion of customer needs into a product and shows how much value is added from each step to the product. There are three types of activities identified in value stream mapping, namely Non Value Added (NVA), Necessary Non Value Added (NNVA), and Value added (VA).[3]

D. Waste Assessment Model (WAM)

Waste Assessment Model (WAM) is a model, which was developed to simplify the search for waste problems and identification to eliminate waste.[4]

1) Seven Waste Relationship: All types of waste are inter-dependent and affect other types of waste. The seven wastes can be grouped into three categories that are related to man, machine, and material. The man category contains the concepts of motion, waiting, and overproduction. The machine category includes overproduction and waste, while the material category includes transportation, inventory, and defects. To calculate the strength of waste relationship, a measurement with questionnaire was developed.

2) Waste Relationship Matrix (WRM): Waste Relationship Matrix (WRM) is a matrix used to analyze measurement criteria. The row in the matrix shows the effect of a particular waste on the other six wastes, while the column in the matrix shows the waste that is affected by other waste. The diagonal of the matrix is placed with the highest relationship value and by default, each type of waste will have a primary relationship with the waste itself. Waste matrix illustrates the real relationship between types of waste.

3) Waste Assessment Questionnaire (WAQ): Waste Assessment Questionnaire (WAQ) is made to identify and allocate waste that occurs on the production line. This assessment questionnaire consisted of 68 different questions, which were introduced for the purpose of determining waste. Each question questionnaire represents an Element of Work, a condition or a trait that might give rise to a certain type of waste.

E. Value Stream Mapping Tools (VALSAT)

1) Process Activity Mapping (PAM): Is a technical approach that is commonly used in activities on the production floor. However, this expansion of PAM can be used to identify lead time and productivity in both physical product flow and information flow, not only within the scope of the company but also in other areas of the supply chain. The basic concept of PAM is to map every phase of activities that occur starting from operations, transportation, inspection, delay, and storage. Then classified into types of value activities, namely value added, necessary non value added, and non value added. The purpose of this mapping is to help understand the process flow, identify waste, identify whether a process can be reorganized to be more efficient, and identify improvements to the flow of value added.[3]

2) Supply Chain Response Matrix (SCRM): Is a graph that illustrates the relationship between inventory and lead time, so that it can be seen an increase or decrease in inventory levels and distribution time in each area in the supply chain. From the functions provided, it can then be used as a management consideration for estimating stock needs if it is associated with achieving short lead times. The aim is to improve and maintain service levels.[3]

3) Production Variety Funnel (PVF): It is a visual mapping technique that attempts to map the amount of product variation at each stage of the manufacturing process. This tool can be used to identify the point where a generic product is processed into a number of specific products. In addition, this tool can also be used to show the bottleneck area in the design process. With these functions, it can then be used to plan improvements to inventory policies. [3]

4) Quality Filter Mapping (QFM): Is a tool used to identify the location of quality defect problems in the existing supply chain. Evaluation of quality loss that often occurs is done for short-term development. This tool is able to describe three types of quality defects, namely product defects, scrap defects, and service defects.[3]

5) Demand Amplification Mapping (DAM): The map is used to visualize changes in demand along the supply chain. This phenomenon embraces the law of industrial dynamics, where demand transmitted along the supply chain through a series of order and inventory policies will experience increasing variations in each movement from downstream to upstream. From this information can be used in decision making and further analysis both to anticipate changes in demand, adjust fluctuations, and evaluate inventory policies.[3]

6) Decision Point Analysis (DPA): Shows a variety of different production system options by trade off between the lead time of each option and the inventory level needed to cover during the lead time process.[3]

7) Physical Structure Mapping (PSM): It is a tool used to understand supply chain conditions at the production level. This is necessary to understand the condition of the industry,
how it operates, and in directing attention to areas that may not have received enough attention for development.\(^3\)

**F. Failure Mode Effect Analysis (FMEA)**

FMEA serves to identify the sources and root causes of a problem. Modes of failure that occur vary, namely defects in design, conditions outside the specified specifications, and changes in the product resulting in changes in product function.\(^5\)

**G. Roller Conveyor**

Roller conveyor is a conveyor system which is the main focus of goods to be transported. Rollers in this system are slightly different from rollers on other types of conveyors. Rollers on the roller conveyor system are specially designed to fit the condition of the goods being transported, for example rollers are given a rubber coating, anti-corrosion coating, and so on.

**H. One Piece Flow**

One Piece Flow is a method for reducing lot size in the manufacturing process. The reduced lot size will support the setup process and make it faster. The smaller the lot size, the better the flow that is in the process. Ideally, lot size should be reduced to one. Small lots can easily pass between processes, facilitate layout changes to connect processes to cells, eliminate double-handling, and reduce the inventory and space needed to store them. Thus, problems related to quality and process will be seen quickly. Problem solving must be done immediately, because there is no inventory reserve that is usually used to hide inefficiencies in the process.\(^6\)

**III. RESEARCH METHODOLOGY**

Stages of research can be described in the research methodology flowchart as shown in Figure 1.
Start

Introduction
Conducting observations and interviews directly at PT. Kati Kartika Murni

Problem Identification
There is discrepancy between production amount and order

Research Objectives
Increase the production of Carton Box using Lean Manufacturing Approach

Data Collection
1. General company data
2. Actual data and ordering of carton box production at PT. Kati Kartika Murni
3. Working hours data
4. Processing time data

Data Processing
1. Calculation of time, normal time, and default time
2. Manufacturing Lead Time Calculation (before)
3. Process Cycle Efficiency Calculation (before)
4. Takt Time Calculation
5. Current State Value Stream Mapping
6. Waste identification, with:
   6.1. Waste Relationship Matrix
   6.2. Waste Assessment Questionnaire
   6.3. Value Stream Analysis Tools
   6.4. Process Activity Mapping before improvement
7. Failure Mode Effect Analysis (FMEA)
8. Conveyor Manual Plan
9. Simulation
10. Manufacturing Lead Time Calculation (after planning)
11. Process Cycle Efficiency Calculation (after planning)
12. Process Activity Mapping Calculation (after planning)
13. Future State Value Stream Mapping

Design improvements and analysis of results
Design improvements by replacing operator driven manual conveyor with automatic roller conveyor to reduce the transportation time from corrugator workstation to flexo.

Conclusions and suggestions

End

Figure 1. Research methodology flowchart
IV. DISCUSSION

A. Manufacturing Lead Time Calculation (Before)

Manufacturing lead time is the total time taken to determine the entire processing time in the product manufacturing process. In the manufacturing lead time calculation it is known that the total value added time is 7917.1 seconds, necessary non value added is 8191 seconds, and non value added is 1703.6 seconds. Manufacturing lead time in the process of making cardboard boxes is 17811.7 seconds.

B. Process Cycle Efficiency Calculation (Before)

Calculation of the process cycle efficiency to see the general condition of the plant is to assess the efficiency of the process cycle, because by using this metric, it can be seen how the percentage between processing time and the overall production time carried out by the factory. Process cycle efficiency in the process of making cardboard boxes by 44.4489%.

C. Takt Time Calculation

Takt time calculation is the data of carton box product request and working hours, so the takt time obtained is 4,645 seconds per 1 kg of product. After calculating the manufacturing lead time and takt time, the manufacturing lead time is greater than the takt time which results in the production target not being reached at the specified time. As an effort to meet production targets, company need to make improvements to the production process to increase the effectiveness and efficiency of the production process.

D. Current State Value Stream Mapping

![Current state value stream mapping](image)

E. Waste Assessment Model (WAM)

The calculation of the seventh waste relationship is done by discussing using weighting criteria. The question of the relationship of the seven wastes, carried out with 31 explanations of the relationship of the seven wastes. The results of this questionnaire data processing will get the total value that will be made into the Waste Relationship Matrix (WRM). The total value obtained is the result of conversion of the results obtained on the questionnaire.
From Table I. above, we get the three biggest wastes. Waste contained in the results of the questionnaire was a defect of 23.3792%, transportation amounted to 16.044%, and inventory amounted to 15.8798%. The results of the recapitulation of the waste assessment results will be used as one of the multipliers to find the tools that will be used in Value Stream Analysis Tools.

F. Value Stream Analysis Tools (VALSAT)

The concept of Value Stream Analysis Tools is used in the selection of detailed mapping tools by multiplying the results of the weighting of waste from the results of WAQ with a multiplier score scale according to the weight of the seven tools.

<table>
<thead>
<tr>
<th>Map. Tool</th>
<th>Bobot</th>
<th>PAM</th>
<th>SCRM</th>
<th>PVF</th>
<th>QFM</th>
<th>DAM</th>
<th>DPA</th>
<th>PSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overproduction</td>
<td>13.5229</td>
<td>13.5229</td>
<td>40.5688</td>
<td>0</td>
<td>13.5229</td>
<td>40.5688</td>
<td>40.5688</td>
<td>0</td>
</tr>
<tr>
<td>Waiting</td>
<td>12.7846</td>
<td>115.062</td>
<td>115.062</td>
<td>12.7846</td>
<td>0</td>
<td>38.3539</td>
<td>38.3539</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>16.044</td>
<td>144.396</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16.044</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>3.94493</td>
<td>35.5043</td>
<td>0</td>
<td>11.8348</td>
<td>3.94493</td>
<td>0</td>
<td>3.94493</td>
<td>0</td>
</tr>
<tr>
<td>Inventory</td>
<td>15.8798</td>
<td>47.6394</td>
<td>142.918</td>
<td>47.6394</td>
<td>0</td>
<td>142.918</td>
<td>47.6394</td>
<td>15.8798</td>
</tr>
<tr>
<td>Motion</td>
<td>14.4444</td>
<td>130</td>
<td>14.4444</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Defects</td>
<td>23.3792</td>
<td>23.3792</td>
<td>0</td>
<td>0</td>
<td>210.413</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>509.504</td>
<td>312.993</td>
<td>72.2588</td>
<td>227.881</td>
<td>221.841</td>
<td>130.507</td>
<td>31.9238</td>
<td></td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
TABLE III
PROCESS ACTIVITY MAPPING (PAM)

<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>Production/Process Activity</th>
<th>Tools</th>
<th>Distance (m)</th>
<th>Time (delta)</th>
<th>Operator</th>
<th>Flow</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Incoming Area</td>
<td>Paper roll inspection</td>
<td>Forklift</td>
<td>356.454</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Paper roll transfer from warehouse to production floor</td>
<td>Paper roll assembly and set up of corrugator machine</td>
<td>Forklift, conveyor manual</td>
<td>472.268</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Corrugator</td>
<td>Corrugating process</td>
<td>Conveyor manual</td>
<td>590.531</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Corrugated sheet inspection</td>
<td>Corrugated sheet inspection before delivery</td>
<td>Conveyor manual</td>
<td>725.406</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sheet loading onto conveyor</td>
<td>Sheet loading onto conveyor</td>
<td>Down Stacker, conveyor manual</td>
<td>720.522</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Goods awaiting to be staged as WIP</td>
<td>Goods awaiting to be staged as WIP</td>
<td>Conveyor manual</td>
<td>542.373</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Strapped carton box transfer to WIP area</td>
<td>Strapped carton box transfer to WIP area</td>
<td>Conveyor manual</td>
<td>505.522</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Strapped carton box transfer to delivery loading area</td>
<td>Strapped carton box transfer to delivery loading area</td>
<td>Conveyor manual</td>
<td>590.531</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE IV
FAILURE MODE AND EFFECT ANALYSIS (FMEA) TRANSPORTATION

<table>
<thead>
<tr>
<th>Waste</th>
<th>Potential Failure Mode</th>
<th>Potential Effect(s) of Failure</th>
<th>S</th>
<th>Potential Cause(s) of Failure</th>
<th>O</th>
<th>Correct Process Controls</th>
<th>D</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Material damaged by conveyor</td>
<td>Partially discarded</td>
<td>7</td>
<td>material friction with conveyor</td>
<td>6</td>
<td>Put the material stacked more neatly</td>
<td>8</td>
<td>336</td>
</tr>
<tr>
<td>L</td>
<td>Long material transfer time between workstations</td>
<td>Production target not achieved</td>
<td>7</td>
<td>Material transfer is still manual and there is no value added activity</td>
<td>8</td>
<td>rectification have not done yet</td>
<td>8</td>
<td>448</td>
</tr>
</tbody>
</table>

G. Waste Analysis

After using the waste assessment model and value stream mapping analysis tools, the highest waste weights are defects and transportation. The next waste analysis uses Failure Mode and Effect Analysis (FMEA) to identify problems and obtain recommendations for improvement. After obtaining the root of the problem with the highest RPN of each waste that occurs using Table IV. Failure Mode and Effect Analysis (FMEA), then recommendations for improvements will be made that are expected to reduce or eliminate the waste that occurs.

TABLE V
FAILURE MODE AND EFFECT ANALYSIS (FMEA) CONVERSING

Waste transportation gets the highest order of the seven types of waste identified by Process Activity Mapping (PAM). The use of FMEA to analyze waste transportation has the highest RPN value of 448 which is available at the time of operation and long material movement in the production floor area. Material transfer time between workstations is long because the material transfer is still manual and there is no control done by the company.

H. Improvement

Proposed improvements made to reduce or eliminate waste transportation in the problem of material transfer between old work stations due to manual material transfer is to add roller conveyor as material handling between corrugator and flexo work stations. As well as the occurrence of one piece flow for the corrugating process to flexo. From the result of the draft calculation, obtained the proposed conveyor capacity (Q) = 7.524 kg/s and total conveyor time (t) = 350.87 seconds.

I. Manufacturing Lead Time Calculation (After Planning)

Manufacturing lead time is the total time taken to determine the entire processing time in the product manufacturing process. In manufacturing lead time calculation, it is known that the total value added time is
7917.12 seconds, necessary non value added is 7411.56 seconds, and non value added is 305.52 seconds. Manufacturing lead time in the process of making cardboard boxes is 15634.2 seconds.

J. Process Cycle Efficiency Calculation (After Planning)

Calculation of the process cycle efficiency to see the general condition of the plant is to assess the efficiency of the process cycle, because by using this metric, it can be seen how the percentage between processing time and the overall production time carried out by the factory. Process cycle efficiency in the process of making cardboard boxes by 50.64%.

K. Future State Mapping

![Future State Value Stream Mapping](image)

Figure 3. Future state value stream mapping

L. Conclusion

- Manufacturing lead time before improvement is 17811.7 seconds, Process cycle efficiency before repair is 44.4489%, and takt time is 4.645 seconds.
- The use of the Waste Assessment Model to identify the waste that occurs in the production process of cardboard boxes produces defects and transportation as the highest waste that occurs.
- The chosen Value Stream Analysis Tools (VALSAT) is Process Activity Mapping (PAM), which is to identify activities contained in the production process. The total time for the biggest activity is in the transportation activity.
- The use of the Failure Mode and Effect Analysis (FMEA) to analyze waste transportation has the highest RPN value of 448 found during the time of operation and long material movement in the production floor area.
- The design of improvements made to reduce or eliminate waste transportation in the problem of material transfer between old work stations due to manual material transfer is to add roller conveyor as material handling between corrugator and flexo work stations. As well as the occurrence of one piece flow for the corrugating process to flexo.
- Manufacturing lead time after the design improvement is 15634.2 seconds. Process cycle efficiency after the design improvement is 50.64%.
- Demand is 3600 boxes. Before the design of production improvement is 3379 boxes, and after the design of improvement is 3850 boxes. After the design improvement, production results are increased and achieved.

REFERENCES