Identification and proposed strategy for minimizing defects using the lean six sigma method in the pallet production process

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ABSTRACT

The object of this research is a company engaged in the manufacture of pallets and dunnage. In the pallet production process, there is still a lot of waste and defective products. The primary purpose of this study is to identify and propose strategies to minimize defective products through the critical to quality (CTQ) search stage that occurs. This study uses the lean six sigma method as a solution to overcome these problems. On the pallet found 3 CTQ products, namely cracked, broken, and moldy. Based on the waste assessment model (WAM) questionnaire distribution, it is known that the most dominant waste is defect waste. The improvement proposals obtained are making standard operating procedures (SOP), making checklists for machine replacement and maintenance, conducting operator training, procuring safety equipment, and creating a special place for raw material storage.

ABSTRAK

Perusahaan yang menjadi objek penelitian bergerak dalam bidang pembuatan pallet dan dunnage. Dalam proses produksi pallet masih banyak terjadi pemborosan dan produk cacat. Tujuan utama dari penelitian ini adalah untuk mengidentifikasi dan mengusulkan strategi untuk meminimalkan produk cacat melalui tahap pencarian critical to quality (CTQ) yang terjadi. Penelitian ini menggunakan metode lean six sigma sebagai solusi untuk mengatasi permasalahan tersebut. Pada pallet ditemukan 3 produk CTQ yaitu retak, pecah, dan berjamur. Berdasarkan penyebaran kuesioner waste assessment model (WAM), diketahui waste yang paling dominan adalah waste defect. Sehingga usulan perbaikan adalah membuat standar operasional prosedur (SOP), membuat checklist untuk penggantian dan perawatan mesin, melakukan pelatihan operator, pengadaan peralatan keselamatan, dan membuat tempat khusus untuk penyimpanan bahan baku.

1. Introduction

The research object is a company that produces pallets and dunnage, which is located on the connecting highway Cilegon Banten. There are two types of pallets produced, namely 115 cm x 115 cm x 12 cm, and 90 cm x 90 cm x 10 cm. As for the dunnage produced, there are two sizes, namely 4.5 cm x 9 cm x 30 cm, and 9 cm x 9 cm x 50 cm. The function of the pallet and dunnage is to place shipping goods that are stored in the warehouse so that it can facilitate the movement of goods of various sizes. The company has several machines, namely planner, grinding, cutting, oven, and shaving machines. The company uses a make-to-order system based on orders from consumers. Orders that come usually vary every month according to pre-orders that come from consumers. One of the efforts to improve the quality of a product is to minimize waste in the production process. Waste means all work activities that do not add value to transforming inputs into outputs along the value stream. There are seven categories of waste, namely overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion, and defects [1].

The problem that often occurs is the discrepancy between the number of products received and the number of products ordered by consumers caused by defective products such as cracks, breaks, and mold caused by the water content of pallet products being above 20%. In addition, another problem that occurs is excessive production in pallet production, with the number of existing orders from January 2018 to December 2019 as many as 8860 pieces. However, the company produces 9463 pieces due to defective products, so they must be remade to make a difference of 603 pallets from the plan production.

In addition, non-value-added activities are still found, such as waiting activities in the assembly, testing, and refining processes, which of course, will result in waste due to these activities. The lean concept aims to turn waste into something of value from the consumer's point of view [2]. Therefore, one way to reduce defects is to take a six sigma approach because it focuses on reducing problems and variations in the process to obtain more effective improvements [3].

Lean six sigma is a systemic approach to identify and eliminate waste or things that are not of added value using radical continuous improvement to achieve six sigma performance levels [4]. The purpose of lean six sigma is to increase customer value by increasing the ratio between added value to waste [5]. Therefore, a combination of lean and six sigma is needed because lean cannot bring the process under statistical control, while six sigma cannot significantly increase process speed [6]. Waste in this company will result in losses to the company. The company's loss is the increase in raw materials used in the pallet production process. Therefore, companies must know which activities allow increased value-added, reduced unnecessary activities (waste), and cut the production time. One alternative method that can minimize waste and improve product quality is the lean six sigma method.

2. Research Methodology

The measure of failure in six sigma, which shows failures per million opportunities, is called defects per million opportunities (DPMO). The six sigma control target is 3.4 DPMO. DPMO shows how many errors will occur if an activity is repeated one million times [8-9]. In completing a particular project to reach the six sigma level, the six sigma team needs to be guided by the 5 phases of DMAIC [10]. This concept is used for process improvement projects by implementing five steps called DMAIC (define-measure-analyze-improve-control)[11]. Lean six sigma is a systemic approach to finding the most dominant waste in a production process and eliminating non-value-added activities through continuous improvement processes. Lean six sigma focuses on wasting data obtained to find out where the problems are in the company's work system so that the causes of these problems are known, and improvements are made (Gaspersz, 2002) [5]. This research data is processed using the lean six sigma method using the DMAIC cycle, but the control stage in this study is not used because it is the company's authority.

The following is a description of the research flow in general. The first stage, the literature study, aims to understand the theories related to the research conducted. Literature studies can be done using trusted sources such as journals. The second stage is to make problem boundaries so that this research focuses on one problem and does not get too broad. The limitation of the problem in this research is the study focuses on the pallet production process. The data used is data from January 2018 to December 2019. The analysis uses the DMAIC (define-measure-analyze-improve-control) concept, which is only carried out until the improvement stage in the form of an improved design. The third stage, data collection used in the form of primary data and secondary data. Preliminary data obtained through observation and interviews, while secondary data obtained from the company.

The last stage, data processing using the lean six sigma method through several steps, namely preparing the required data, knowing critical to quality (CTQ), knowing the type of waste by distributing questionnaires to three people to find out what types of waste occur and the most dominant in the pallet production process, understanding the sigma value, calculating the sigma value from January 2018 to December 2019 to find out whether the pallet production process still requires improvement in the production process or not, knowing the current process cycle efficiency (PCE) to determine the efficiency value of pallet production process, knowing the importance of risk priority number (RPN) by using failure mode and effect analysis (FMEA) by multiplying the severity, detection and occurrence of various causal factors, providing suggestions for improvement, providing recommendations for improvement of the factors causing the product to occur disabled so can minimize product defects that occur, determine future process cycle efficiency (PCE), and provide suggestions for improvement.

3. Results and Discussion

3.1. Define

Define is the first step in six sigma. This stage aims to identify the problem to be solved and improve its quality [12]. The define stage consists of drawing a SIPOC diagram, identifying waste using a waste assessment model (WAM) questionnaire in the pallet production process, and critical to quality (CTQ) in pallet production. SIPOC is a tool to show workflows and identify suppliers, inputs, processes, outputs, and customers of a process that occurs [13], while critical to quality (CTQ) is a characteristic of a quality directly related to customers' specific needs.

The following is critical to quality (CTQ) in pallet production, i.e., damaged products, cracked products, and moldy products. Damaged products are defects in the form of cracks in the pallet. All cracked and rejected products must be remade. Broken products are defects that occur on the pallet in the form of a break in one part or the dimensions are not following the specifications. *Moldy products* are defects that occur due to mold on one part, which causes the product to become brittle. The waste assessment model (WAM) works more to find problems and objectivity [14]. Based on the waste assessment model (WAM) questionnaire, it is known that defect waste is the most dominant waste that occurs in pallet production with a percentage of 18.26%, as shown in Table 2.

3.2. Measure

It is in the form of DPMO (defects per million opportunities) calculations and sigma values to measure work baselines, including Pareto diagrams and process performance measurements (P-Chart). A Pareto chart is a tool for sorting data from frequency/value in descending order [15]. For example, based on the Pareto diagram, it is known that crack defects are the highest defect with a percentage of 76.9%, as shown in Figure 4. The P chart is a control chart for the number of non-conformance units. A manufacturing process may be used to create this control chart [16]. For example, the computation of pallet product control limits from January 2018 to December 2019 is shown in Figure 5.

Based on the p control chart, it is known that there are still 3 data that are out of the upper limit and 2 data that are out of the lower limit, and this indicates that the pallet product is still not under control and needs improvement in its production. DPMO is a step in calculating the probability of failure per one million opportunities [17]. Based on Table 3, it can be seen that the pallet production of PT Sinar Cahaya Mulya as many as 8860 units with a total of 603 units of defects to obtain a DPMO value of 552,018.79 and a sigma value of 3.521. Based on Figure 6, it is known that the current state results are 81.41% for value-added, 6.90% for non-value added, and 11.69% for non-value-added necessity.

Figure 1. Cracked product

Figure 2. Broken product

Figure 3. Moldy product

Table 1. Production and defect data

Year	Period	Pallet production	Number of defects (Unit)	Year	Period	Pallet production	Number of defects (Unit)
2018	January	400	45	2019	January	275	33
	February	400	28		February	300	26
	March	375	42		March	300	30
	April	400	27		April	375	26
	May	375	29		May	350	16
	June	450	20		June	350	19
	July	400	21		July	300	18
	August	375	40		August	320	21
	September	475	33		September	320	19
	October	475	32		October	320	16
	November	450	13		November	350	22
	December	375	19		December	350	8
Total		4,950	349	Total		3,910	254

Table 2. WAM questionnaire results

F/T	O	I	D	M	T	P	W	Total	Presentase (%)
O	10	6	4	6	4	0	4	34	14.78
I	6	10	6	4	6	0	0	32	13.91
D	6	8	10	6	6	0	6	42	18.26
M	0	6	4	10	0	4	6	30	13.04
T	4	6	4	4	10	0	4	32	13.91
P	4	4	4	4	0	10	6	32	13.91
W	6	6	6	0	0	0	10	28	12.17
Total	36	46	38	34	26	14	36	230	100
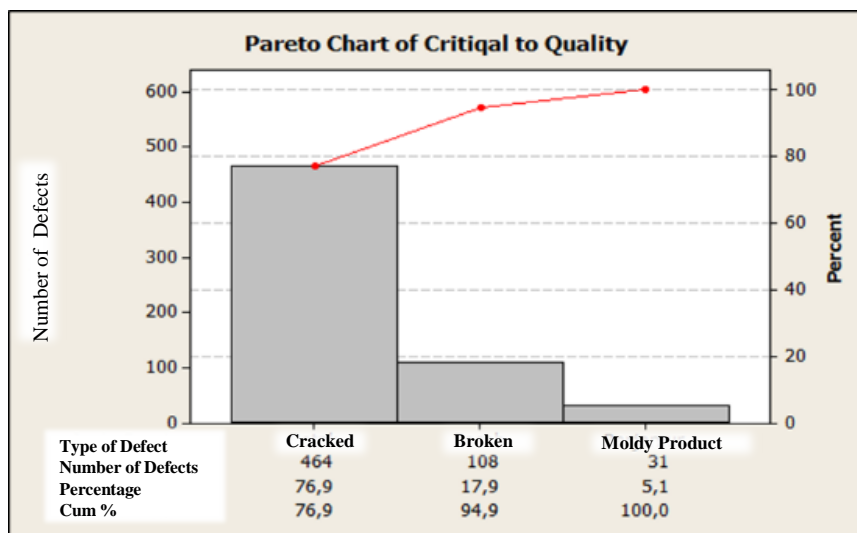
Figure 4. Pareto diagram
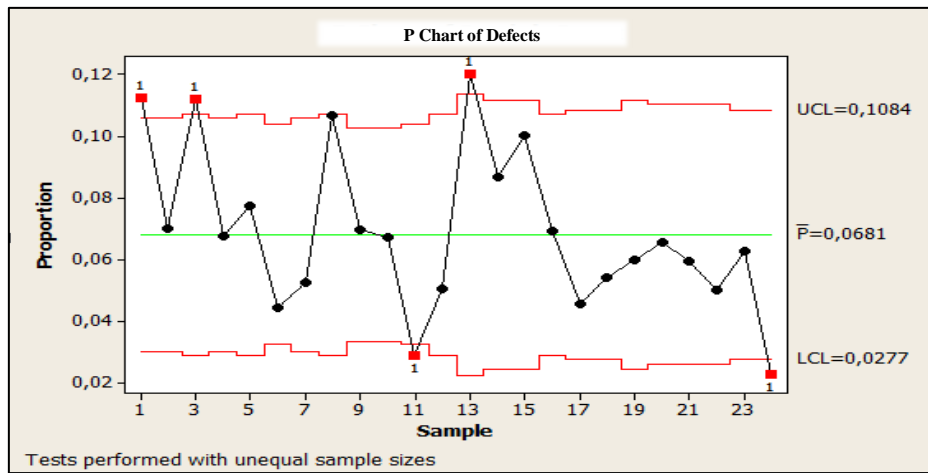
Figure 5. P chart

Table 3. DPMO of pallet production

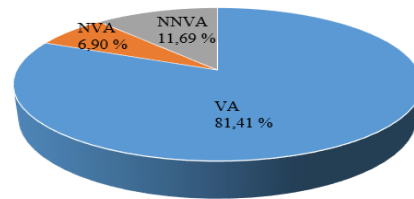| Unit	8860
Defect	603
CTQ	3
DPMO	553,018.79
Sigma value	3.521

Figure 6. Percentage of production activity

3.3. Analyze

At the analyze stage, an examination is carried out both on the fact and data processors to get a clear picture of the cause of an obstacle/problem [12]. At this stage, an analysis of the problems that occur will be carried out using fishbone diagrams and FMEA. Fishbone diagrams function to find the elements that cause problems [6] and cause and effect diagrams [18]. Figure 7 shows five factors causing the problem. The first factor is human, skilled labor caused by a lack of experience. The second factor is machines: machine maintenance that is not carried out regularly causes reduced engine performance. The third factor is the improper method, the wrong way to use the oven machine causes the wood moisture content to change. The fourth factor is the materials: raw materials used in nasty conditions cause difficulties in moisture content drying. The fifth factor is the environment: the operator's health condition deteriorates caused by the dust room.
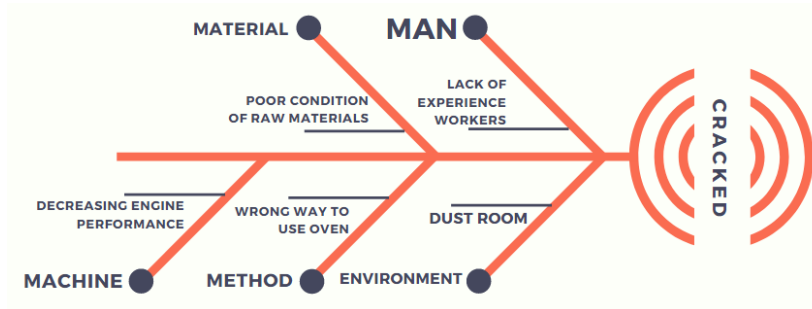

Figure 7. Fishbone diagram

Failure mode effect and analysis (FMEA) can identify and assess the risks associated with potential failure [19]. FMEA can detect potential failures and their impact on the operation of the product and identify steps for solving existing problems [20]. According to Table 4, the order of priority for improvement is as follows: the failure mode with the highest RPN value is inappropriate in drying the moisture content of the wood (224), followed by reduced engine performance (196), less-skilled labor (90), and difficulty in drying the moisture content of the wood (224).

3.4. Improve

The following are suggestions for improvement of the problems that occur:
1. Make SOPs for the combustion process so that workers are not wrong in using the oven machine to prevent defective products from occurring.
2. Make a checklist for regular machine replacement and maintenance.
3. Conducting training for operators so that new workers can understand how to use machines properly to prevent defective products from occurring.
4. Create a special place for storing raw materials to maintain the quality of raw materials.
5. Using safety equipment so that the health condition of the operator who works can be maintained from lousy air.

6. Proposed future value stream mapping. This proposal is carried out by minimizing non-value-added activities, namely by eliminating waiting activities at the assembly, testing, and refining stations by adding an auxiliary tool in the form of a trolley so that direct transportation uses a trolley.

    Based on Figure 7, it is known that for the future state, the results are 87.41 % for value-added, 0% for non-value added, and 12.55 % for necessary non-value added.

Table 4. Failure mode effect and analysis

| No	Mode of failure	Cause of failure	Degree of saverity	Frequency of occurance	Change of detection	Risk priority number	Rank	Action planning
1	Unskilled Workforce	Lack of experience	6	5	3	90	3	Conduct training for operators
2	Operator's health condition is declining	Dusty room	3	5	2	30	5	Using safety equipment properly
3	Difficult in drying moisture content	Raw materials used are not in good condition	4	6	3	72	4	Create a special place to store raw materials
4	Wrong way to dry wood moisture content	Wrong way to use oven machine mesin	8	7	4	224	1	Making SOP for the combustion process
5	Low engine performance	Machine maintenance that is not done routinely	7	7	4	196	2	Make checklists for machine replacement and maintenance
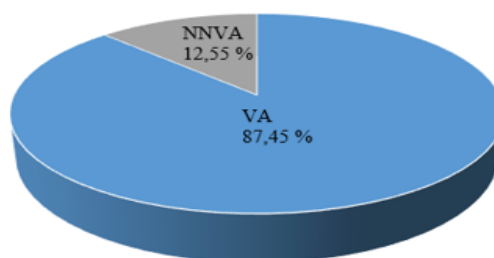
Figure 8. Percentage of future State pallet production activity

4. Conclusions

This study concludes that the CTQ in the pallet production process is cracked, broken, and moldy. The types of waste in the pallet production process are defect waste, waste overproduction, inventory waste, processing waste, transportation waste, motion waste, and waiting waste. The sigma value in the pallet production process is 3.521. The results for the lack of experience factor get a value of 90, the dusty room factor gets a value of 30, the factor of raw materials used in nasty conditions gets a value of 72, and how to use the wrong oven machine gets a value of 224. The factor of machine maintenance that is not carried out regularly gets value 196. Periodically get a value of 196. Proposed improvements made to minimize defective products in the pallet production process are improvement of SOPs, manufacture of maintenance checklists and replacement of spare parts, provision of training to operators, safety equipment, and the manufacture of Special Places for Storage of raw materials. The percentage of process cycle efficiency (PCE) in the pallet production process when the current state is 81.41% and for the future state is 87.45%, so that there is an increase of 6.04%.

Acknowledgements

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