Reducing waste to improve product quality in the wooden pallet production process by using lean six sigma approach in PT. XYZ

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Abstract. This company is a company engaged in wood processing. The product produced by this company is wooden pallets. The problems that are found by this company is waste in the production process that are the high defective products and non value added activities. The average disability percentage of wood pallets is 7.52% of the total production per month. The value exceeds the disability tolerance of the company that is 5%. This study proposes to reduce the number of defective products and eliminates non value added activities through design improvement. This problem can be solved by using Lean Six Sigma approach which is a combination of the Lean and the Six Sigma concept with the DMAIC method by providing improvements to increase the number of defective products and eliminate non value added activities. By using the Lean Six Sigma method can provide lean metrics and sigma level calculation values. Based on actual study, the result for the lead time is 212.58 minutes, the process cycle efficiency is 64.40%, the process velocity is 0.0041 processes / hour. Based repair 70.73%, process velocity is 0.0035 processes / hour.

1. Introduction
The quality of product is defined as the degree or level where the product or service is able to satisfy the desires of customers (fitness of use). The quality of product is its ability to provide appropriate performance or results, even in excess of what customers want. Quality is the basic factor of the customer to get the product. To maintain the consistency of the product produced and in accordance with the demand of market, it is necessary to do a quality control on the production activities [1].

PT. XYZ is a company engaged in wood processing. The company produces products in the form of wooden pallets. One of the most important equipment in the world of warehousing is a wooden pallet. The use of wooden pallets is very important because it can provide convenience in logistics packaging. Therefore, wooden pallets are a product that has a high level of demand.

In the manufacture of wooden pallet, PT. XYZ has problem, that is waste in the production process that are the high defective products and non value added activities. Based on data of the number and percentage of product defects wooden pallet during 2019 it can be seen that the average percentage of defective products is 7.52%, while the company sets a target for defective products below 5%. Product defects will cause losses and decrease customer confidence so it needs to be improved. This product defect occurs because there are no operational standard provisions that are used as a reference in production activities and there is waste in the form of rework activities which cause the production
cycle time to be longer. By using the Lean Six Sigma approach which is a combination of Lean concepts and Six Sigma concepts with the DMAIC method, it can solve problems that occur in the company.

Previous research through the Lean six sigma DMAIC (Define, Measure, Analyze, Improve, Control) approach of process improvement for printing operations, the company was unable to meet the projected demand of 200,000 boards, the company had a maximum output of 143,400 from two printing machines. With the application of the Lean Six Sigma method, it was found that around 30% of workers’ activities were found to be non-value-added activities and many machine delays were found to cause decreased productivity [2]. On the off chance that the consequences of QC tests can't satisfy the acknowledgment models, the aftereffects of examination of the entire arrangement of the estimations on that day must be eliminated or should be re-dissected, and an incomplete or full re-approval of the strategy considered [22].

According to J.E Guerrero, small furniture companies also reduce waste and increase productivity as well. This research was conducted to identify problems in the manufacturing process and opportunities for improvement. The results show that applying the Lean Six Sigma method has the potential for companies to reduce defective products by 25 percent, reduce waste by 13 percent, and increase sales productivity by about 14 percent in the first year [3,4].

Defects in the welding process are classified into two types of defects, namely cracks and porous welding results. Based on the defect analysis using a fishbone diagram and 5 why tools, it is explained that the process that produces the biggest defect product is the welding process so that it will be centered on this process and the alternative chosen to make improvements is to form a team and SOP supervisors and make training so that the skills and expertise of employees increased [5].

2. Literature Review

2.1. Quality

Quality is a measure of how capable an item or service meets the needs of consumers according to certain standards. Certain standards may relate to time, materials, performance, reliability or quantifiable characteristics. Quality is also a conformance to specifications, and a level of conformity is a measure of quality. If the specifications do not satisfy customer needs, these specifications must be changed [6]. Quality has some different dimensions that can be used as a basis for strategic and analyst planning for manufactured products. The following some dimensions are performance, features, conformance, reliability, durability, serviceability, aesthetics, perceived quality [7]. According to Montgomery, quality is something that is decided by the customer. Quality is based on the customer's actual experience of the product or service, measured based on the customer's requirements and always represents a target that moves in a competitive market [8].

2.2. Quality Control

Quality control is the use of techniques or activities to achieve, maintain and improve the quality of a product or service. The purpose of quality control is to quickly investigate the causes or shifts of the process so that an investigation of the process and corrective action can be taken before too many inappropriate units are produced. The ultimate goal of quality control is to reduce product variability [6].

2.3. Lean Six Sigma

2.3.1. Lean Concept. Lean is a continuous improvement effort to eliminate waste, increase value added products (goods and or services) and to provide value to customers (customer value) [9]. There are 5 basic principle of Lean, i.e:
• The value of the product or service is identified from the customer perspective, where the product or service that the customer wants is a superior quality product at a competitive price and on time product delivery
• Value flow process mapping or process mapping in the value stream for each product or service needs to be identified
• Waste that does not add value to all activity during the value stream process should be eliminated
• Uses a pull system in the processing so that materials, information, and products flow smoothly and efficiently throughout the value flow process
• Various techniques and tools for improvement (tools and repair techniques) are sought to achieve perfection and continuous improvement.

2.3.2. Waste. Waste is a waste of activities and does not add value to the product, but instead adds to the burden of resource consumption [10]. According to Suhartono in the Toyota Production System, there are seven wastes in the production process, namely over production, waiting, transportation, processing, inventory, movement and production defects[11].

2.3.3. Six Sigma. Six sigma is a continuous improvement efforts to reduce variations in the process in order to increase the capability of the process in producing products (goods or services) that are error free (zero defects - a minimum target of 3.4 DPMO (Defect Per Million Opportunities) and to provide value to customers (customer value) [8]. Implementation of Six Sigma to improve the quality of products consists of five phases of DMAIC (Define, Measure, Analysis, Improve and Control) [12] i.e:

• Define is the first stage in the DMAIC cycle which aims to define customer problems / opportunities, processes and requirements, because the DMAIC cycle is iterative, process problems, flows, and requirements must be verified and updated throughout all other phases for clarity.
• Measurement is the second stage in the DMAIC cycle, which identifies the first measurement and collects, processes and presents data
• Analysis is the third stage in the DMAIC cycle, where careful inspection of the process is carried out
• Improve is the fourth stage in the DMAIC cycle, where solutions and ideas are created and decided creatively. Once a problem is identified, measured, and analyzed, potential solutions can be determined to solve the problem.
• Control is the last stage in the DMAIC method, where once the solution is estimated, the measurement does not stop to follow and verifies the stability of the improvement and the predictability of the process.

2.3.4. Lean Six Sigma Approach. Lean six sigma is defined as a business philosophy, a systemic and systematic approach to identifying and eliminating non-value added activities through radical continuous improvement to achieve six sigma performance levels.

2.4. Value Stream Mapping
Value flow mapping is a lean manufacturing method for showing and improving the flow of inventory and information needed to produce a product or service that is delivered to consumers using symbols, metrics and arrows. A value flow map is a visual representation that allows one to determine where waste occurs [13]. Value stream mapping is a tool which enables a company to map the process flow that helps in identifying various factors like;

• Value added time (time taken for producing the end product),
• Non Value added time (time taken which do not contribute to the production of end product),
Cycle time (time required to perform a process) and
Changeover time (time required to change tool and programming etc.).

3. Methodology
Researchers conducted research at PT. XYZ, and the research was carried out from February 2020 to March 2020. The object used in this study was wooden pallets. There are 2 types of data collected, namely:

- Primary data is data receive by researchers directly, interviews and direct measurements in the field [14]. Primary data gather including production process time, sequence of the production processes load time machine and engine set-up time data, rating factor and allowance.
- Secondary data is data that has been collected and processed by other parties so that it does not need to be sought by researchers but only to quote that is the amount of production, the attribute data quality, the number of disability attributes and common data company.

The steps taken in this study began with a discussion to identify problems that occur in the production process. So a preliminary study can be done to find out the problem solving methods that can be used. Data collection is carried out for data processing. Then data processing is performed using the lean six sigma method to analyze the quality of wooden pallets.

4. Result and Discussion

4.1. Define
Define phase is done to identify the main problems to be solved. The define phase that will be described in the form of Project Statement, product selection, SIPOC diagram, Value Stream Mapping, and Voice of Customer. Products that will be the research object is wooden pallet.

4.2. Measure

4.2.1. Calculation Standard Time. Measuring time is a job that observes and records the working hours of both elements and cycles using tools that have been prepared by researchers such as stopwatches, observation sheets, and writing instruments [15].

After obtaining and applying standard time, the data will be processed first by conducting a uniformity and adequacy test. Based on the results of the recapitulation, it can be concluded that all the measurement time data are uniform and sufficient.

4.2.2. Processing of product quality data. The quality characteristics of each inspection are cracks, moldy black and arise nails as follows:

- Crack (R) is a disability in which there is a separate, fibrous section of the wooden pallet extending apart.
- Nails Arising (PT) is a defect where there are nail tips that arise in a wooden pallet
- Moldy Black (HB) is a disability where there is a black color on the wooden pallet

Calculation of the value of DPMO and sigma level for examination and obtained as follows.

- Total number of production = 20018 units
• Total defective product = 1507 units
• The level of disability (Defect Per Unit / DPU)

\[
DPU = \frac{\text{Total Defect}}{\text{Total number of Production}}
\]

\[
= \frac{1507}{20.018} = 0.0753
\]

• Critical To Quality (CTQ) = 3
• Defect per Million Opportunities (DPMO)

\[
DPMO = \frac{DPU}{CTQ} \times 1.000.000
\]

\[
= \frac{0.0753}{3} \times 1.000.000 = 25.1000
\]

Sigma level calculation by interpolation
From the above data obtained DPMO is between 24.998 and 25588 and sigma values between 3.46 and 3.45, then do interpolation to get the DPMO sigma level of 25.100,

\[
(DPMO-X_2) \times (X-Y_2) = (X_1-DPMO) \times (Y_1-X)
\]

\[
(25.100-24.998) \times (X-3.46) = (25.588-25.100) \times (3.45-X)
\]

\[
X = 3.46
\]

• Calculation of sigma level

\[
= \text{NORMSINV} \left( 1 - \frac{DPMO}{1,000,000} \right) + 1.5
\]

\[
= \text{NORMSINV} \left( 1 - 25.100 \right) / 1,000,000 + 1.5
\]

\[
= 3.46
\]

From sigma level calculation, the sigma value is 3.46 with DPMO 25.100, this shows that for every 1,000,000 times the possibility of disability production is 25,100. To increase the value of this sigma, it is necessary to identify and analyze the causes of the processes that produce defective products so that they can provide the expected repair solutions to increase the current level of sigma.

4.2.3. Lean Metrics Actual. The lean metric measurement is done to know the condition of a factory from the lean point of view. The measurement of this metric will provide an initial overview of the company's condition before applying Lean and if Lean has been applied there will be a change in the value that is better in these metrics [16]. Lean metrics calculations performed consist of calculations of manufacturing lead time, calculations of process cycle efficiency, calculations of process lead time, and calculations of process velocity. The separation between value added activities and non-value added activities is done to make the efficiency of the calculation process cycle, process lead time, and process velocity.

\[
\text{Process Cycle Efficiency} = \frac{\text{Value Added Time}}{\text{Total Lead Time}}
\]

\[
= \frac{136.91}{212.58} \times 100\% = 64.40\%
\]

Average speed of completion = \( \frac{\text{Total Production in a month}}{\text{Number of Working Days}} \)
\[
\text{Process Lead Time} = \frac{\text{Number of Products in Process}}{\text{Average speed of completion}} = \frac{20018}{68} \approx 293 \text{ days}
\]

\[
\text{Process Velocity} = \frac{\text{The number of activities in the process}}{\text{Process Lead Time}} = \frac{29}{293} \\
= 0.099 \text{ process/day} \\
= 0.0041 \text{ process/hour}
\]

4.3. Analyze

The analysis is carried out by making Pareto diagrams, causal diagrams and five why diagrams which serve as a tool to further analyze the results obtained in the measurement stage.

4.3.1. Pareto diagram. The reason for using the Pareto diagram is to find out how the percentage of defects is compared to the number of defects that occur. What must be done first is that the types of defects are sorted by the largest percentage, then calculate the cumulative percentage. The Pareto Principle (also known as the 80-20 rule) states that for most events, about 80% of the effects are due to 20% of causes [17]. The Pareto diagram showing the order of the disabilities of each disability attribute can be seen in Figure 1.

Based on the 80-20 rule, the type of disability that must be further analyzed is the type of disability that has a cumulative percentage under 80%, namely

- Crack (R) with a cumulative percentage of 36.80%
- Nails Arising (PT) with a cumulative percentage of 70.90%

4.3.2. Cause and Effect Diagram. One of the methods / tools to improve quality is a fishbone diagram. This diagram is often referred to as a Cause-Effect diagram [18]. The reason for using this diagram is to help organize information about the potential cause of a problem. The resulting analysis includes an analysis of humans, work environment, machines and equipment, work methods and material attributes of the acquired disabilities.
4.3.3. Five Why Diagrams. The 5 Why analysis is a structured approach that asks why repeatedly to understand the causes of this problem, and for effective corrective action to be generated to reduce incidents, and prevent accidents from happening again. At this stage, results will be obtained which will be continued for later processing at the fishbone diagram stage [19]. The Five Whys diagram is a diagram that is used to reveal the root cause of the cause of the non-conformity obtained from the cause and effect diagram so that it can be corrected appropriately by continuing to ask why something is not appropriate until it finds the root of the problem. The five whys diagrams were obtained from causal diagrams and from observations on the production floor and from brainstorming with the company.
### Table 1. Table five why diagram on crack

| Problem | Why | Why | Why | Why | Why |
|---------|-----|-----|-----|-----|-----|
| Crack   | Careless operator in positioning wooden pallet | Inaccurate operator inside position wooden pallet | Operators do not get enough training | The company has no time to carry out training for operator | The company focuses on producing wooden pallet according to production target |
|         | Wood raw material is not good | Damaged engine parts | Lack of engine maintenance | The operator is not responsible | Lack of communication between operators during the drying process |
|         | Engine performance is not good | Damaged engine parts | Lack of engine maintenance | There is no routine maintenance schedule | There is no work procedure |

A diagram of five why for the attribute of nails arrising can be seen in Table 2.

### Table 2. Table five why diagram on nails arrising

| Problem | Why | Why | Why | Why | Why |
|---------|-----|-----|-----|-----|-----|
| Nails arrising | Operator are less thorough during the assembly process | The operator is not responsible | Uncomfortable work environment | Lack of lighting | The company focuses on producing wooden pallet according to production target |
|          | Incorrect device setting | The operator is not thorough | Inexperienced operator | Operators do not get enough training | Lack of supervision on the operational side |
|          | Inaccuracy during the assembly process | Lack of supervision on the production floor | There is no standardization of assembly process | There is no work procedure | The company focuses on producing wooden pallet |

### 4.4. Improve

The improve phase is an approach taken to reduce waste in the production process. The improve phase that was carried out was the application of work place management (work place management), 5S method (*Seiri* / Sort, *Seiton* / Stabilize, *Seiso* / Shine, *Seiketsu* / Standardize, and *Shitsuke* / Sustain).

#### 4.4.1. 5S

5S (*seiri*, *seiton*, *seiso*, *seiketsu*, *shitsuke*) is a five-step structuring and maintenance of the workplace that is developed through intensive efforts in manufacturing. When translated into Indonesian, these five steps for maintaining the workplace are referred to as 5S (*Seiri*, *Seiton*, *Seiso*, *Seiketsu*, and *Shitsuke*) with understanding as follows [20]: The explanation of 5S is as follows:
• **Seiri** (Sort) is the activity of sorting piles of wood scraps from the results of cutting, wood chips from wood chips, boxes containing paint cans from painting, storage of used equipment such as hammers, wood nails, rivets, iron plates.

• **Seiton** (Stabilize) is an activity to regulate hammers, rivets, wooden nails, iron plates, roll meters and paint piloxes placed in equipment racks based on their type so that they are easy to retrieve when needed, storage shelves are given visual markings making it easier to retrieve or return tools back.

• **Seiso** (Shine) is the activity of cleaning the machine from scrap leftover from wood chips and equipment used so that the tool's performance remains good when using it, and making procedures and a cleaning schedule for each worker

• **Seiketsu** (Standardize) is an activity to carry out tasks such as operator training, machine maintenance implemented and carried out consistently.

• **Shitsuke** (Sustain) is a self-discipline regarding training for operators, machine maintenance and evaluating for future improvements

4.4.2. Estimated Improvement Results. Transportation and waiting time is a factor in waste. If this waiting time and transportation can be eliminated, the processing speed can be increased. Therefore, the proposal given is to eliminate waiting time activities that might be eliminated.

| Lean metrics                  | Before          | After           |
|------------------------------|-----------------|-----------------|
| Number of Production Activities | 29 process    | 25 process    |
| Manufacturing Lead Time      | 212.58 minute  | 193.56 minute  |
| Value-Added Time             | 136.91 minute  | 136.91 minute  |
| Non Value-Added Time         | 75.67 minute   | 56.65 minute   |
| Process Cycle Efficiency     | 64.40 %        | 70.73 %        |
| Process Velocity             | 0.0041 process/hour | 0.0035 process/hour |

4.5 Control
Standard Operating Procedure (SOP) is a guideline that contains standard operating procedures in an organization that are needed to ensure that every decision, step or action and use of processing facilities taken by people in an organization can run effectively, consistently standards and systematically. An organization is said to have a good system if the availability of good SOPs [21]. At the analysis stage, the main problems in the production process of wood pallets are the process of reducing the water content in the wood pallets, and in the process of assembling the wood pallets. Production defects that occur due to lack of machine usage procedures, work procedures in producing wooden pallets and lack of supervision. To overcome this, it can be done by making good work procedures in every part of the production process.

5. Conclusion
The conclusions obtained based on data processing and problem solving analysis that have been carried out are as follows: Calculation of lean metrics in the actual condition shows that the total manufacturing lead time is 212.58 minutes, process cycle efficiency is 64.40% and process velocity is 0.0041 processes / hour. Based on the estimation of the proposed improvement, the results of manufacturing lead time are obtained of 193.56 minutes the process cycle efficiency of 70.73% and the process velocity of 0.0035 processes / hour. An increase in the process cycle efficiency of 6.33% shows that the wood pallet production process is better than before. The sigma value achieved by the company at the quality inspection stage is 3.46. Proposed improvements made to improve production quality and process speed are improvements by applying the 5S method which includes training of
operators, carrying out machine maintenance schedules, improving methods and work environment and maintaining communication between the company and the suppliers.

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