# Waste Identification in Production Process Using Lean Manufacturing: A Case Study

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**Abstract**

*All manufacturing industries need to perform continuous efforts to survive in the current competitive and challenging market. In order to manage the critical situation, the stakeholders are trying to implement the most recent and innovative technique to the production system. The aim is to attain effective and efficient. One important step to reach efficient working process is by understanding wastes occurred along the production line and try to reducing their presence. Lean manufacturing approach is one of the powerful philosophies to guide a company to improve their quality, by providing varieties of tools and strategies. This approach is able to help company in many sectors, such as identification and elimination of waste, better quality of product and service, lowering the production cost, reducing the human effort and the production process time. In this study, a small industry was chosen as the object of the research. In this research, lean manufacturing approach is used to identify waste in the production process and increase the value added activities throughout the process. The aims are to increase the process cycle efficiency and becoming lean. Based on the analysis, it can be seen that current process cycle efficiency is only 28.49% which means the production process still relatively un-lean. From the current state value stream mapping, lead time, work-in-process goods, and stock became the main problems that need to be solved. In order to tackle that, this study has proposed new production schedule and is able to increase the process cycle efficiency to 41.36%.*

**Keyword: lean manufacturing, waste identification, process cycle efficiency**

## Introduction

The concept of lean has received a lot of attention from practitioners and researchers after being published on Toyota Production Systems by Taiichi Ohno. Toyota being the first company that implement this approach and gain success. According to Ali (2019), there are benefits gained from successful implementation of lean manufacturing approach, such as improvement in manufacturing operations, productivity, quality which lead to a better cash flow. However, at the very early stage of lean implementation, less than 10% of British companies are able to success. The reason was lack of understanding of lean concept, organization culture, top management who are not supportive, and lack of information sharing during the implementation of lean techniques (Marvel and Standridge, 2009).

Lean manufacturing also defined as a philosophy which is continuously identifying and eliminating waste resulting in the production process in order to maintain the smooth production flow (Chahal, 2012). One of the basic principles of lean is to reduce or eliminate waste arising in the production process, where waste is viewed as any use or loss of resources that does not lead directly to creating the product or service. There are seven types of waste identified by Shigeo Shingo (Hines and Taylor, 2000):

1. Over-production is a production which has too much product or too soon and causes disruption of the flow of information or goods, and excess inventory.
2. Defect is frequent errors that occur in the process, product quality problems, or poor performance in distribution.
3. Unnecessary inventory is in the form of storage resulting in excessive cost and poor customer service.
4. Inappropriate processing is a waste caused by the work processes using the procedures and systems which do not conform to the ability of an operation.
5. Excessive transportation is a waste caused by the displacement of materials, information, goods, and human.
6. Waiting is a condition which need a long periods of idle for people, information or goods.
7. Unnecessary motion, this waste is closely related to ergonomics. Occurrence of unnecessary movement caused by the poor organization of the workplace.

Lean focuses on continuous improvement of customer value, through the identification and elimination of activities that are not value-added. According to George (2002), lean has several objectives as follows:

1. Eliminate wastes that occur in the form of time, energy, and materials during the production process.
2. Produce products according to the customer's order.
3. Reduce costs along with improving the quality of the end product.

This present work use lean manufacturing approach to identify waste that occurs in the production floor. The study was conducted in a local industry that produces traditional cake. By identifying the existence of wastes in the production line, the company is able to improve the efficiency. To determine the process and the flow of material in the production process, value stream mapping being used as the first step to identify the waste. Next step, waste assessment model will be used to determine and rank the influence of the waste. This model can also identify another waste which not visible when the value stream mapping is developed. Further, fishbone diagram is used to analyze the cause of waste. Finally, the study is aiming at the increase of process cycle efficiency and becoming lean.

**Methodology**

This paper has several phases as follows:

1. Identification
   The phase of identification is done by describing the value stream mapping as a first step to identify the waste from the production process of cake. Value stream mapping (VSM) is a technique used as an initial step in the process of change to get a firm condition of lean production process (Goriwondo et al, 2011). According to Hines and Taylor (2000) the value stream is defined as a specific activity within a supply chain that is necessary for designing, ordering, and the determination of a specific product or value. According Lovelle (2001) when the value stream mapping has been made, waste would have to be identified and eliminated in order to cut lead time and increase the percentage of value added activity, in terms of changing production systems in batch and push production system to one-piece flow and pull.

2. Data Processing
   Identification of waste requires a model that facilitates and simplifies the process of finding the problems of waste. The assessment method that be used is waste assessment model which consists of two stages, namely waste relationship matrix to determine the relationship between waste and waste-assessment questionnaire that be used to assess what types of waste that occurs and which one is dominate another. Rawabdeh (2005) stated that waste assessment model is a model that was developed to simplify the way to search and identify waste. This model describes the relationship between the seven wastes with the symbol O for overproduction, P for unnecessary process, I for inventory, T for excessive transportation, D for defects or errors in the production process, W to waiting, and M for unnecessary motion. All types of waste are affecting each other in the sense that in addition to giving effect to the other types of waste, also simultaneously affected by other types of waste.

   To determine the strength of the relationship between wastes, it should be weighted. The value of this weighting is obtained from questionnaires given to the respondent that associated with the waste under this study. Weighting value will then be converted into scores range linkages between wastes. Then, it is used to develop waste relationship matrix (WRM). Next stage of this model is the use of waste-assessment questionnaires (WAQ). Waste-assessment questionnaire was made to identify and categorize waste that occurs on the production line (Kurniawan, 2012). This questionnaire consists of 68 items which each question represent different events. The advantage of this model is the simplicity of the matrix and the questionnaire that able to achieve accurate results in identifying the root cause of waste (Rawabdeh, 2005). The score result obtained from questionnaires completed by the production manager, head of production, and the employee in all departments of the production process of cake.

3. Data Analysis
   After describing in detail the production process by using VSM, Value Stream Mapping Analysis Tool (VALSAT) will be used to analyze it. This tool is used to map in detail the flow of values that focus on value-added processes (Hines and Rich, 2007). There are seven types of value stream analysis tools such as process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis, and physical structure. In this study, the selection of it obtained from final weighting result using WRM and WAQ to decide the appropriate tools. Basically, details on the mapping of these tools can be used to find the cause of waste that occurs (Hines and Rich, 1997). Further, fishbone diagram is used to determine the root cause of waste.

## Result and Discussion

### Current State Value Stream Mapping of Cake Production Process

The production process begins with an order made by customer which estimated by each branch. After that, the amounts of order that sent to the head of production are calculated. Together with the production manager, the head of production make a daily production schedule. The cake production process can be seen in figure 1:

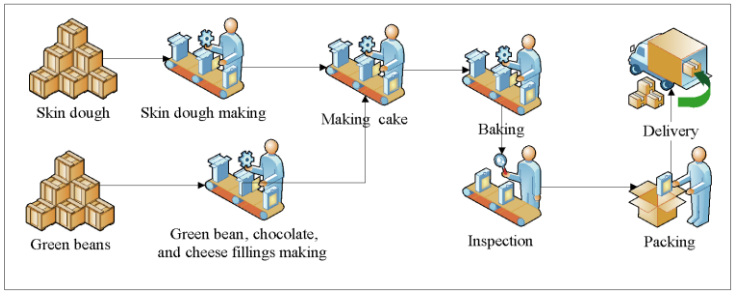


Figure 1. Production process

Based on the current state value stream mapping in figure 2, there were inventory waste which characterized by the existence of work-in-process goods and final stock in the cake production process. The total time for the storage activity is 70,200.00 seconds, coupled with 71149.20 seconds of waiting activity that produced work-in-process goods. As a result the lead time of production process became longer and less efficient.

The total lead time for the production process of the cake is 104087.96 seconds. This lead time consists of cycle time for each department, transportation or material handling, storage time, and waiting time. From the current state of value stream mapping the problem that occur in the production process are the existence of work-in-process goods (WIP), final stock, and the long lead time.

Process cycle efficiency (PCE) is used to calculate the current state performance. PCE can help to identify a process whether it is a value added process or not. Here is the assessment of process cycle efficiency of cake production process in this study:

$$PCE = \frac{Value\ added\ time}{Total\ Lead\ Time} = \frac{29653{,}03\ sec}{104087{,}96\ sec} \times 100\% = 28{,}49\%$$

According to George (2012), most processes are un-lean if the process has less than 30% in the process cycle efficiency. It means more than 70% of the time is consist of non-value added activity. Based on the assessment above, the value of PCE for the current state value stream mapping in the production process of cake is 28.49%, which means the cake production process is un-lean and can be improved.

### Waste Identification

Waste assessment model is used to identify waste in each department. To get the accurate data, respondents are determined. The respondents must answer the questions in the waste assessment questionnaire about the waste that occurs in the production line and about the waste that probably occurs caused by another wastes.

The result of the questionnaire then be assessed and ranked by using waste assessment model. Based on the assessment, overproduction was arising in the cake process making. This waste was the biggest waste that affected the whole production process. Overproduction is not only as a waste that influences the process but also as a waste that caused another waste arise in the production process. Meanwhile, the waste that occurs as a result of the influence from another waste in each department was varies. Summary of the percentage of waste that arises in the production process cake provided in table 1.

Table 1. Waste Relationship Percentage

| Department | Waste Relationship | |
|---|---|---|
| | From | To |
| Skin dough making | Overproduction (17,74%) | Motion (19,35%), Waiting (19,35%) |
| Green bean filling making | Overproduction (17,02%), Inappropriate Process (17,02%) | Defect (19,15%) |
| Chocolate and cheese fillings making | Overproduction (18,18%) | Overproduction (17,36%), Inventory (17,36%), Defect (17,36%) |
| Cake making | Overproduction (20,00%) | Inventory (19,09%) |
| Baking and Packing | Overproduction (17,36%) Inappropriate Process (17,36%) | Inventory (19,83%) |
| Whole Process | Overproduction (21,00%) | Overproduction (18,00%), Waiting (18,00%) |

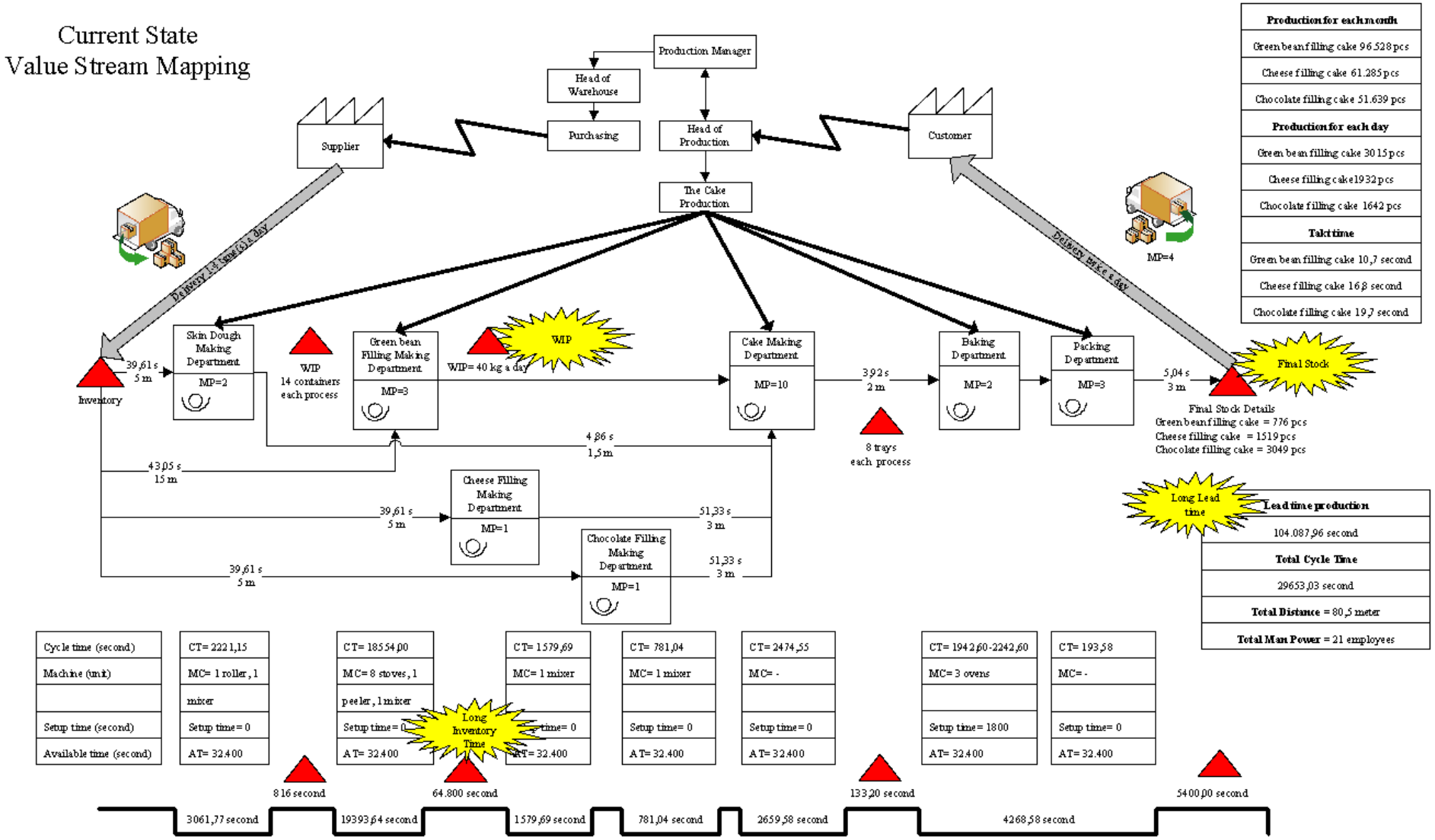


Figure 1. Current State Value Stream Mapping

Based on Waste Assessment Questionnaire (WAQ), overproduction has the biggest percentage of waste as seen in Figure 2. In this case, overproduction caused the arising of motion waste and waiting waste in skin dough making department. For green bean filling making, overproduction and inappropriate process were the cause of defect, while in baking and packing department those waste caused the existing of inventory. For department of other fillings making, overproduction caused inventory while at the same time it caused the arising of waiting activity for the whole process.

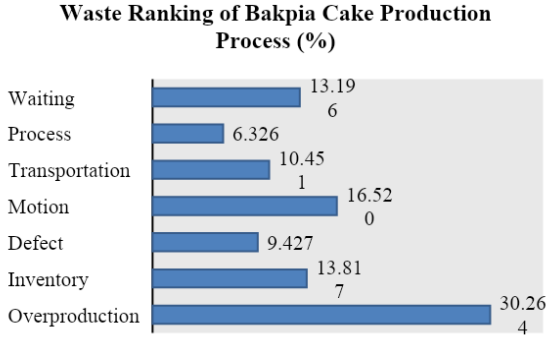


Figure 2. Summary of WAQ

**Waste Cause Analysis**

After the identification of waste, the next step is to analyze the causes of waste occurrence. Waste of overproduction, motion, and inventory were the big three wastes that arise in the cake production process and then those were processed using fishbone diagram. In this paper we summarize the result using table as follows:

1. Overproduction

   Based on a fishbone diagram there are twelve major causes of overproduction. One of the causes is the unbalanced work time in each department because of the variation of process time and the difference workload. Summary of overproduction causes can be seen in table 2:

Table 2. Causes of the Overproduction Waste

| No | Major Causes | Minor Causes |
|---|---|---|
| 1 | Processing time for each department is not the same | a. Different processing time each station<br>b. The workload is not equal |
| 2 | Employee finished the production too fast | a. Avoid overtime<br>b. In order to finish the production quickly |
| 3 | Additional demand | a. Out of stock from branch |
| 4 | Concern of low in stock | a. Reducing the occurrence of overtime during weekend<br>b. Avoid loss sales |
| 5 | Incorrect estimation | a. New employee, less-experience employee |
| 6 | Unpredictable demand | a. Customer`s visit and purchase in outlets and production house<br>b. Bulk purchasing |
| 7 | Make to stock and make to order production systems | a. Avoid return of goods<br>b. The company fulfills the huge demand of cake |
| 8 | Weekend safety stock | a. Avoid loss sales<br>b. Reducing overtime during weekend |
| 9 | Production not according to the production schedule and production target | a. Production based on the amount of material (e.g. skin dough making) |
| 10 | New variant based on the seasonal materials | a. To get more attention from customer |
| 11 | Optimize the capacity of machine | a. Tools and machine cost efficiency |
| 12 | Production based on capacity | a. Help the employee to avoid from repeatable activity |

The production system in the small industry are both make to stock and make to order production according to the demand of customers. However, at the end of the week, the management try to anticipate the number of stock for weekends and holidays. This condition triggered overproduction. Overproduction that occurs in the production process does not lead to the return of products because production management has an additional handling of packaging, especially for chocolate and cheese fillings by vacuuming process. But this vacuuming activity then becomes an additional process that is not value-added and should be minimized. Overproduction can also mean that the supply of a product is too fast compared to the demand required by customers, including customers in the production process cake indeed. In this study, processing time of making skin dough, making chocolate and cheese filling, and making cake are too fast. As a result, work-in-process goods increased significantly in these departments.

2. Unnecessary Motion
   Motion is the second rank of waste that occurs in the cake production process. Here, employee and machine movements are categorized as a motion, but some additional motions that is not the standard process known as unnecessary motion. These activities do not add value to a product and generate additional activity that should not be done. Most of the unnecessary motion is due to the lack of a reliable machine, thus requiring additional human motion that must be repeated. In addition, the limitation on the machine capacity, less-tidy work area also led to a motion waste. For example in the production process, especially in chocolate and cheese filling making department, the working area is not well-arrange, so that, employee are often looking for needed tools.
3. Inventory
   Inventory is waste consequence from overproduction effect. Inventory led to an extra handling that should be avoided. Inventory also cause an extra work, extra storage space, and the extra cost of handling. Unbalance work flow and stock are the most visible and frequent cause from inventory.

**Value Stream Analysis Tools**

Value stream analysis tools is used to analyze the value stream by using weight score derived from the assessment process of waste matrix relationship (WRM) and waste assessment questionnaire (WAQ). The result of those assessments is used to select the appropriate tools in this study. PAM (Process Activity Mapping) is chosen to analyze the flow of production and identify waste that occurs. According to Hines and Rich (2000) PAM is one of the appropriate tools to analyze value stream mapping. Observation was held to make a detail process that include in the cake production process. The data of time for each activity is taken by using stopwatch. Here is the summary of the activity categories based on process activity mapping:

Table 3. Summary of Process Activity Mapping

| **Waste Category** | **Sum of Activity** | **Time (second)** |
|---|---|---|
| VA | 23 | 29653.03 |
| NVA | 5 | 3490.40 |
| NNVA | 31 | 70944.53 |
| Total | 59 | 104087.96 |
| **Activity Category** | **Sum of Activity** | **Time (second)** |
| Operation | 23 | 29653.03 |
| Transportation | 27 | 392.15 |
| Inspection | 2 | 352.38 |
| Storage | 2 | 70200.00 |
| Delay | 5 | 3490.40 |
| **Activity Category** | **Sum of Activity** | **Time (second)** |
| Total | 59 | 104087.96 |
| %VA | | 28.49 % |
| %NVA | | 3.35 % |
| %NNVA | | 68.16 % |

Based on the table 3, the time required for the entire process of making cake is 104,087.86 seconds. Activities that occur in the production process then categorized into the value-added activities, necessary but non value-added activities, and the non-value-added activities. In the whole process of making cake contained 28.49% of time spent on value-added activities, 68.16% for necessary but non value-added activities 3.35% of non-value-added activities.

**Proposed Value Stream Mapping**

As seen in the current state value stream mapping in figure 2, lead time, work-in-process goods, and stock became the main problem that need to be solved. From process activity mapping that have been made is known that storage process become the cause of long lead time in cake production process. Besides, inventory is as the result of waste overproduction in the production process. Process of making green bean filling requires about six hours with maximum capacity (40 kilograms).

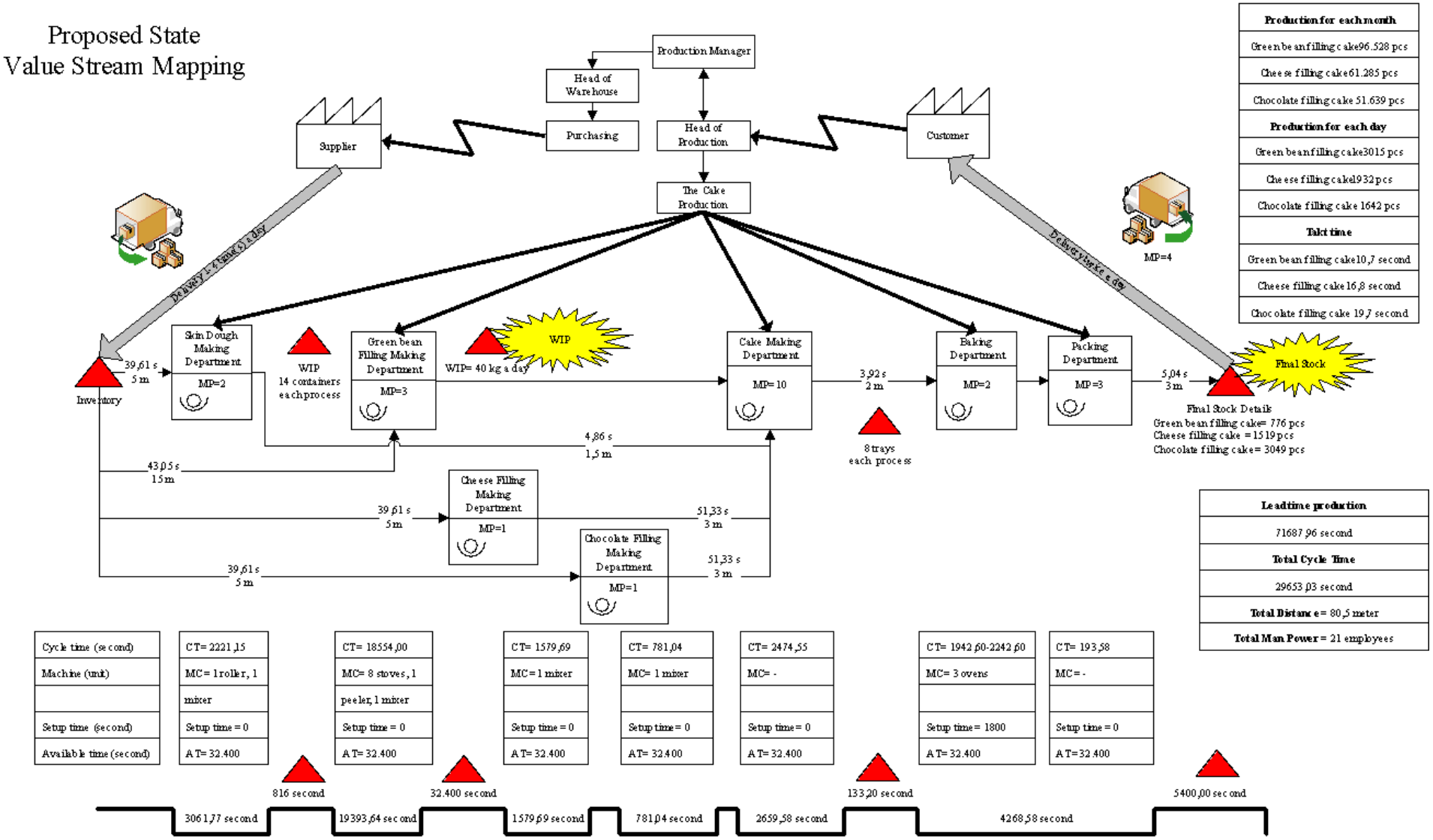


Figure 3. Proposed Value Stream Mapping

In this study, the green bean making department starts to work at 7 am and finishes at 1 pm, after that, green bean filling should be stored for 18 hours before use in the next production day. Green-bean-filling`s storage time can be reduced by a customized working hours. This department can start the process at 4 pm or after the normal shift is finished. As a result, green bean filling which has been produced the night before can be used directly without having long storage. This schedule as seen in figure 3 can reduce half of the storage time. The improvement of the value stream map is done by reducing the storage time of green bean filling from 64800 seconds to 32400 seconds.
Another advantage by changing work schedules for green bean filling making department is reduce the risk of blackout due to power overload. This blackout may disturb the baking process due to the reset of temperature and the time is reset as well.
The proposed value stream mapping was also being assessed of the efficiency of the production process cycle. Process cycle efficiency (PCE) can help to identify whether the stream after the assessment has value added improvement or not. The formula used to calculate the PCE is:

$$PCE = \frac{Value\ added\ time}{Total\ Lead\ Time} = \frac{29653{,}03\ sec}{71687{,}96\ sec} \times 100\% = 41{,}36\%$$

The process cycle efficiency for the proposed value stream mapping is 41.36%. Thus, there was 12.87% increase of PCE value after reducing the storage time in green bean dough filling department by changing the working hours.

**Conclusion**

This study is using lean manufacturing as an approach to solve the company's issues. According to the current state value stream mapping, it is known that total lead time production process is 104,087.96 seconds with total time for value-added activities are 29653.03 seconds. It creates 28.49% of process cycle efficiency. Which means still relatively un-lean and can be improved. Lean manufacturing is known as a method where wastes are identified and removed from the production process. So that, the company is able to have more efficient process. According to the case study, the company suffers from having a huge percentage of necessary but non value added activity. It takes approximately three quarters of all activities. Thus, this study has proposed a customized schedule for the Green-bean-filling`s department. Green-bean-filling`s storage time can be reduced by having new working hours. This proposed schedule can reduce half of the storage time and avoid the blackout risk. As a result, the process cycle efficiency for the proposed value stream mapping is 41.36%.

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