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# Lean Manufacturing Implementation to Reduce Waste Using the Waste Assessment Model Method in the Production Process

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## ABSTRACT

*The research carried out aims to identify, reduce, and hopefully eliminate waste on the Injection Phylon production line using the lean manufacturing concept. One of the tools in lean manufacturing, namely the Waste Assessment Model (WAM) is used to identify waste in the production process. Using the WAM method, it was found that inventory waste is a critical waste with a value of 21.41%, while the second place is defect waste with a value of 20.37% and the third is overproduction waste with a value of 17.49%. After calculating with WAM, calculations are performed using the Value Stream Analysis Tools (VALSAT) to assist in seeing the mapping of existing waste. Using the VALSAT method with the Process Activity Mapping tools, it is found that storage is the largest activity with a value of 85.63%. The critical waste found in this study using WAM and VALSAT is inventory waste. Based on the fishbone analysis, it is found that the root cause of inventory waste is due to the absence of a real-time work order (SPK) information system in the production section and there is no standard identification of manufactured goods.*

***Key Words:*** *Lean Manufacturing, Waste Assessment Model, Value Stream Analysis Tools, Fishbone.*

## 1. INTRODUCTION

The footwear industry is a labor-intensive industry that is very attractive to investors who are competent in their fields. The impact of global political conditions in recent years has led some orders to move to Indonesia and according to data from the Indonesian Ministry of Trade to become the 4th largest footwear producer after China, India and Vietnam. Estimated demand in 2020 will be very large, and this will require a very high level of productivity and good efficiency on the production line. PT. X has several main divisions, one of which is the injection phylon section, which produces midsole-type shoe components. The midsole component that uses Injection Phylon accounts for 90% of orders received and will increase to the level of 95% of orders in 2020.

This increase in orders will directly result in the amount of production made by this section will increase as well. Therefore the potential for increased waste in the production process will increase. According to the theory of Lean Manufacturing, there are 7 wastes that usually occur in the production line, namely excess production, defective products, excess inventory, poor processes, excessive transportation, waiting and unnecessary movements. The production of this part per day is 70,000 pairs, while the demand is 80,000 pairs per day. There is still a gap between production results with good quality and existing demand. Currently, to meet the daily target, additional working hours are made on Saturdays and Sundays. Therefore it is necessary to optimize the injection phylon production line so as to increase production productivity.

Lean manufacturing is one method of increasing productivity which is a requirement in all industries to be able to get a good position in their respective competition.[1][2] If productivity is high, it will automatically have an impact on low costs and high production results, and it is hoped that it will give an indication of low operational expenditures, so that employees or workers will pay more attention to their welfare, including bonuses and guaranteed work safety.

## 2. LITERATURE SURVEY

### Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is one of the methods in lean manufacturing applications.[3][4]. Value Stream Mapping is used as a tool to identify waste from a manufacturing system to find the root of the problem.[4][5]. Detailed analysis of the results of waste identification can be done using the Value Stream Analysis Tools approach or what is known as VALSAT. [6][7]. Studies of the VALSAT method and new mapping tools have been carried out by observing and reviewing its application in 4 types of manufacturing industries namely in the steel manufacturing industry, electronic components, aircraft and automotive.[7][8]. Value Stream Analysis Tool (VALSAT) is used to analyse production waste and give recommendation to improve manufacturing performance. Based on Shigeo Shingo, there are seven wastes that can be identified in production [7]. The main function of VALSAT is to identify and evaluate production [8]. There are seven type of VALSAT tools, i.e. process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping and decision point analysis.VSM is a tools that can lead an industry to a better condition through continuous improvements, communication and process inefficiencies reduction [9]. Flows of information and materials of current production process is visually summarized and evaluated then envisioning a future state map with a better performance [10]. Process activity analysis is used in VSM to evaluate value added and non-value added activities. Value added activity is activity that add value to the product. Taiichi Ohno stated that non-value added activities should be eliminated [11][12].

**Waste Assessment Model (WAM)**

The Waste Assessment Model is a model developed to simplify the search for waste problems and identify them to eliminate waste [13]. This model describes the relationship between seven waste (O: Overproduction, P: Processing, I: Inventory, T: Transportation, D: Defects, W: Waiting, and M: Motion). The waste model is used to measure the relationship between wastes in percentage form and to show the possibility that certain wastes will affect or be influenced by other wastes. The identification of waste requires a model that can simplify the process of finding the problem of waste itself. The assessment method used to look for waste problems is the Waste Assessment Model (WAM) which consists of a Waste Assessment Relationship Matrix (WRM) and a Waste Assessment Questionnaire (WAQ). The advantage of this model is the simplicity of the matrix and questionnaires that cover many things and are able to contribute to achieving accurate results in identifying the root causes of this waste [13][14].

## 3. OBJECTIVE OF THE STUDY

The main objective of this research is to identify and analyze the waste in order to reduce the waste contained in the phylon injection production line in order to meet buyer demand with a lean manufacturing approach. Also comparing which method is the best for analysis tools using VALSAT.

## 4 . RESEARCH METHODOLOGY

The method of analysis in research uses a combination of several methods as follows:

a. Collecting Data with a Walk-Through Survey

In this stage, the researcher will collect secondary data that has obtained permission from the relevant department, to be taken and then processed in a framework relevant to the research objectives. These data include data on company layouts, level of defective products, number of workers, number of products, data on usage of working hours and others that are related to this research.

b. Identification of Waste

- Processing the data from the seven-waste relationship questionnaire into the waste relationship matrix. As well as processing data from the waste assessment questionnaire. So that the results of the first to last waste sequence are obtained. The first and second highest sequences of waste are used as critical waste. With the determination of critical waste, research can be carried out more focused on solving the critical waste.
- Determining the tools to further analyze the causes of waste, namely by using the result of the waste assessment model method into the value stream analysis tools table in order to obtain a sequence of tools that can be used.
- Identification of the causes of critical waste using the fishbone diagram method to find the root causes of critical waste. After it is known that critical waste, alternative improvements and their analysis will be chosen to overcome the root cause of the problem.

c. Analysis

At this stage, an analysis of the results of data collection and processing was carried out previously was done. The analysis includes analysis of the results of critical waste obtained and analysis of the root causes of critical waste using the fishbone diagram method. The process flow research steps are depicted in the figure 1 below.



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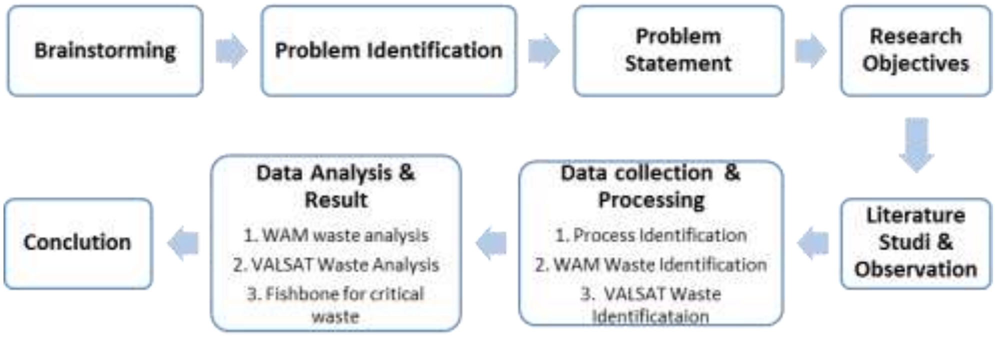


**Figure 1 Research Flow Diagram**

## 5. RESULT AND DISCUSSION

**Waste Analysis**

After grouping and searching for the relationship between the wastes using the seven-waste relationship and waste assessment model, it is continued with processing using the waste assessment questionnaire then continued with weighting using the value stream analysis tools to select the right tools. You get the process activity mapping as the right tool for analyzing the activities in the company.

**Waste Relationship Matrix Value**

Based on the results of the relationship between the waste from the waste relationship matrix, it is necessary to convert the value with the reference given by Rawabdeh (2005), here is the waste model value of the matrix.

Table 1. Waste Model Value

| F/T | O | I | D | M | T | P | W | Score | % |
|---|---|---|---|---|---|---|---|---|---|
| O | 10 | 10 | 6 | 2 | 4 | 0 | 2 | 34 | 14.17% |
| I | 4 | 10 | 4 | 6 | 8 | 0 | 0 | 32 | 13.33% |
| D | 8 | 6 | 10 | 6 | 6 | 0 | 8 | 44 | 18.33% |
| M | 0 | 4 | 6 | 10 | 0 | 6 | 8 | 34 | 14.17% |
| T | 2 | 2 | 6 | 4 | 10 | 0 | 6 | 30 | 12.50% |
| P | 6 | 2 | 4 | 6 | 0 | 10 | 0 | 28 | 11.67% |
| W | 6 | 10 | 6 | 6 | 0 | 0 | 10 | 38 | 15.83% |
| Score | 36 | 44 | 42 | 40 | 28 | 16 | 34 | 240 | 100% |
| % | 15.00% | 18.33% | 17.50% | 16.67% | 11.67% | 6.67% | 14.17% | 100% | |

Based on Table 1., the value of "from defect" and "from waiting" has the largest percentage, namely 18.49% and 15.97%, respectively, which means that if waste defect and waste waiting occur, it has a large enough effect to cause another waste. In addition, the values of "to inventory" and "to defect" have the largest percentage, namely 18.49% and 17.65%, respectively. This can indicate that the waste inventory and waste defects are the ones that are mostly caused by other wastes

**Waste Analysis Based on the Waste Assessment Model**

From the waste assessment model processing, the results of the waste analysis contained in the phylon injection production process in the company are shown in Table 2.



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**Table 2. Waste Model Final Value**

| Rank | Waste Type | Final Percentage |
|---|---|---|
| 1 | Inventory | 21.41% |
| 2 | Defect | 20.37% |
| 3 | Over Production | 17.49% |
| 4 | Un-necessary Motion | 15.50% |
| 5 | Waiting | 11.80% |
| 6 | Transportation | 9.15% |
| 7 | In-appropriate Processing | 4.28% |

Based on Table 2, it can be seen the form and sequence of pareto waste as in the following Pareto diagram:

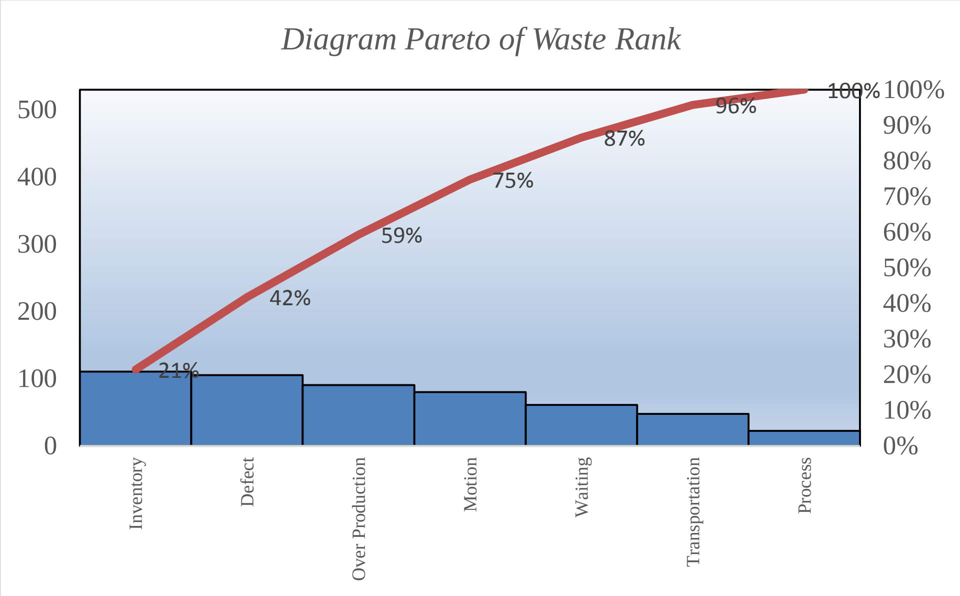


**Figure 2. Pareto Chart of Waste Assessment Calculation Results**

From the processing of WAM data (Table 2.), it is found that in the first place the waste in the phylon injection production process is inventory as much as 21.41%, followed by a waste defect of 20.37% and in the third place is waste over production as much as 17.49%. Furthermore, motion, waiting, transport and process were 15.50%, 11.80%, 9.15% and 4.28% respectively. The critical waste that can be concluded from WAM is inventory waste and defects are the biggest waste that occurs in the phylon injection production process because it is observed that the spindle gear production process itself has a long production lead time, although the time for each production process can be said to be quite short.

The company's provisions for inventory are 3 days production target or only a maximum of 150 thousand pairs. This is due to the necessity of these materials to be stored in storage or warehouse for at least 1 day in each storage process that has been determined.

**Making Current State Map**

Current State Map or map of current conditions which is made based on the actual condition of the company after conducting field observations. The current condition map is created by describing the process flow, material and information from upstream to downstream in the injection phylon section. Here is the Current State Map on the injection phylon line.



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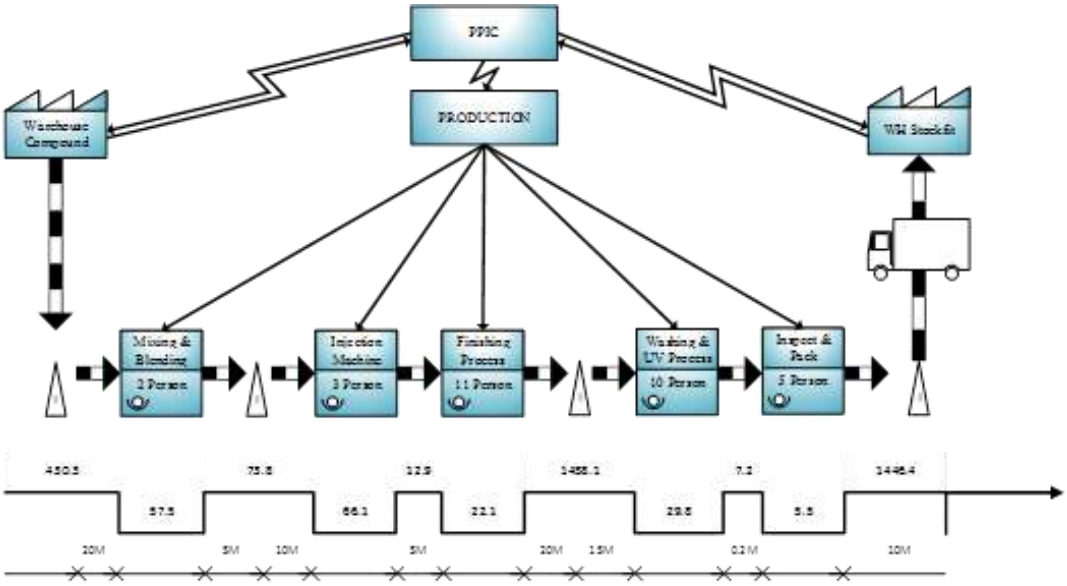


**Figure 3. Value Stream Mapping Injection Phylon**

**Value Stream Mapping Analysis (VALSAT)**

The following is the result of weighting using VALSAT which is used in the selection of tools by multiplying the weighting result of the waste by a predetermined scale.

**Table 3. VALSAT Weighting Results**

| Waste | Weight | PAM | SCRM | PVT | QFM | DAM | DPA | PSM |
|---|---|---|---|---|---|---|---|---|
| Overproduction | 17.49 | 17.49 | 52.48 | | 17.49 | 52.48 | 52.48 | |
| Inventory | 21.41 | 64.22 | 192.67 | 64.22 | | 192.67 | 64.22 | 21.41 |
| Defect | 20.37 | 20.37 | | | 183.31 | | | |
| Unnecessary Motion | 15.50 | 139.49 | 15.5 | | | | | |
| Transportation | 9.15 | 82.37 | | | | | | 9.15 |
| Inappropriate Processing | 4.28 | 38.52 | | 12.84 | 4.28 | | 4.28 | |
| Waiting | 11.80 | 106.18 | 106.18 | 11.8 | 0 | 35.39 | 35.39 | |
| TOTAL | | 468.64 | 366.83 | 88.86 | 205.08 | 280.54 | 156.37 | 30.56 |

Thus, PAM has the largest total of 468.64, so this tool will be used to determine the portion of the activity in detail. Based on PAM, several activities can be seen which are divided based on the above categories, with the following details:

**Table 4. Recap of Phylon Injection Mapping Process Activity**

| Activity | Number of activities | Time (m) | Percentage (%) | Cumulative Percentage (%) |
|---|---|---|---|---|
| Storage (S) | 2 | 1,500.00 | 85.63% | 85.63% |
| Operation (O) | 21 | 169.20 | 9.66% | 95.29% |
| Transportation (T) | 11 | 76.66 | 4.38% | 99.66% |
| Inspection (I) | 2 | 4.34 | 0.25% | 99.91% |
| Delay (D) | 1 | 1.56 | 0.09% | 100.00% |
| Total | 37 | 3,611.76 | | |

From Table 4, the results of grouping activities were divided into 5 activities (delay, waiting, storage, operation, transportation). In the phylon injection production process, there are 37 total activities consisting of 2 activities originating from storage of 85.63%. There were 21 activities originating from operations amounting to 9.66%, and 11 activities originating from transportation activities with a time gain of 4.38%. There are 2 activities that come from the inspection activity of 0.25% and 1 activity for the


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delay of 0.09%. In addition to classification based on 5 activities (delay, waiting, storage, operation, transportation), activity mapping is also grouped based on value added, non-value added or necessary non value adding activity.

**Table 5. Recap of Phylon Injection Activities**

| Recap result of VA, NVA, NNVA | | |
|---|---|---|
| Activity | Total | Percentage |
| VA (Value Added) | 23 | 62.16% |
| NVA (Non Value Added) | 5 | 13.51% |
| NNVA (Necessary But Non Value Adeed) | 9 | 24.32% |
| Total | 37 | 100.00% |

From the table 5, it can be seen that value-added activities have become the largest portion of activities, but there is still room to optimize the process, because 24.32% of activities are NNVA and 13.51% of activities are NVA.

The occurrence of NNVA was mostly done because of the setting, transportation, and several processes that could not be avoided due to the conditions and location of each storage area. Meanwhile, NVA activities that must be reduced are waiting, idling, moving goods using manual methods or using human labor to move them, there is also a process of giving a production code stamp that uses human labor. Of the 5 NVA activities, there are 5 activities that can be improved, these activities can be seen in table 6 below:

**Table 6. Identification of NVA waste to be repaired**

| Number | Activity | Time (menit) | Type |
|---|---|---|---|
| 1 | Waiting For Injection Process (S) | 60 | Storage |
| 2 | Idle cleaning Process | 1.6 | Delay |
| 3 | Transport from Injection machine to Stabilizer (5M) | 12.9 | Transport |
| 4 | Take phylon from stabilizer & move to washing machine | 4.3 | Transport |
| 5 | Waiting For UV Process (S) | 1,440 | Storage |

Of the 5 NVA activities, there are 2 activities that have the greatest time, namely Storage with a total of 1500 minutes. Meanwhile, 3 other NVA activities consist of Delay and Transport with a total time of 18.8 minutes. It can be seen that critical NVA is Storage which takes 98.76% of the total NVA currently available.

**Fishbone Diagram Analysis**

After identifying the waste based on WAM, it shows that the critical waste in the company that is observed is inventory and in PAM identification, the critical waste found is about storage that leads to inventory. Waste inventory is the most critical in the phylon injection production process and is a priority for improvement apart from several other wastes that also need to be repaired



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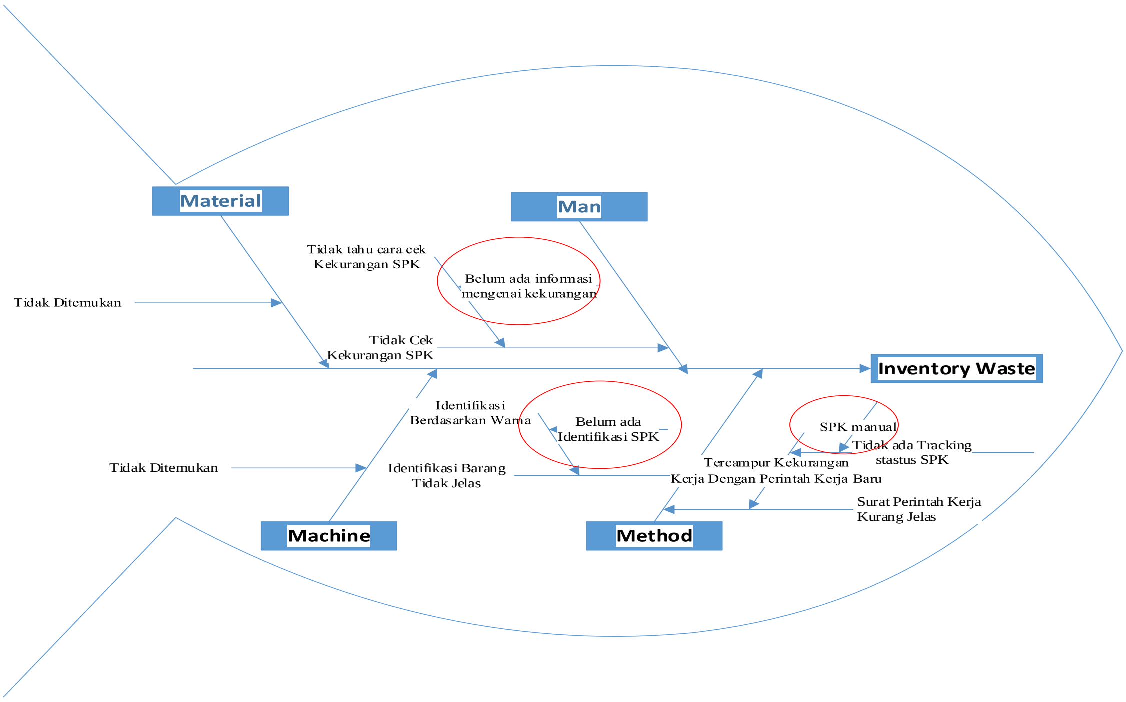


**Figure 4. Fishbone waste critical inventory**

Based on Figure 4, the root cause of waste inventory is based on the following categories:

1. Method

   The buildup of WIP is due to two things that can be seen in the fishbone diagram, including:

   a. The system used to carry out production still uses a manual system, namely a work order is given to the production admin, and then given to the production team in each line, to then be used as a reference for working on production in excel or manual form. Furthermore, the administration team will recap the shortage of production the previous day mixed with the SPK that day. This results in an accumulation of colors and styles that are not required by the rest of the inventory between processes.

   b. The unclear identification of goods causes the mixing of items between certain modes and colors, so that recording and data collection are also often wrong. And lead to longer search times.

2. Humans

   The buildup in inventory was caused by operators who did not know a clear work order that day. This is because the length of the SPK is obtained from the administrative team, while the production targets and machines must continue to run.

**Determination of Improvement Alternatives**

Based on some of the problems above, some alternative improvements need to be done by the company, especially the IP division, recommended for improvements as below:

**Table 7. Recommended improvements**

| Waste | Issue | Recommendations |
|---|---|---|
| Inventory | Work Order is still Manual | Creating an information system regarding online work orders so that it can be immediately used by all sections |
| | Identification of items that are not in accordance with information needs, so it takes a long time to classify according to the needs of the next section | Using barcode identification in accordance with the information needs required by all sections, namely based on the SPK which contains the Model, Style and color of the existing items |
| | Operators do not know shortcomings and work orders according to the time it takes | Providing work order monitors that are integrated with the online work order system according to the SPK and the previous day's production deficiency |



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Using the results from Table 7. regarding recommendations for improvements and also based on brainstorming with management and other interested parties, a draft recommendation for improvement is made.

1. Creating a work order system and production shortages for IP with ERP.

   Purpose: This work order will be incorporated into the existing ERP system and become an additional module for production control. This online SPK will include information on underproduction from the previous SPK or overproduction from the previous SPK, which will be added up with the current new SPK. The production department and finished goods warehouse can more easily identify goods in each intermediate warehouse, this will cut storage from 1500 minutes to a maximum of 180 minutes (88% increase), because employees don't need to search, only 180 minutes of aging process is needed before UV processing the midsole.

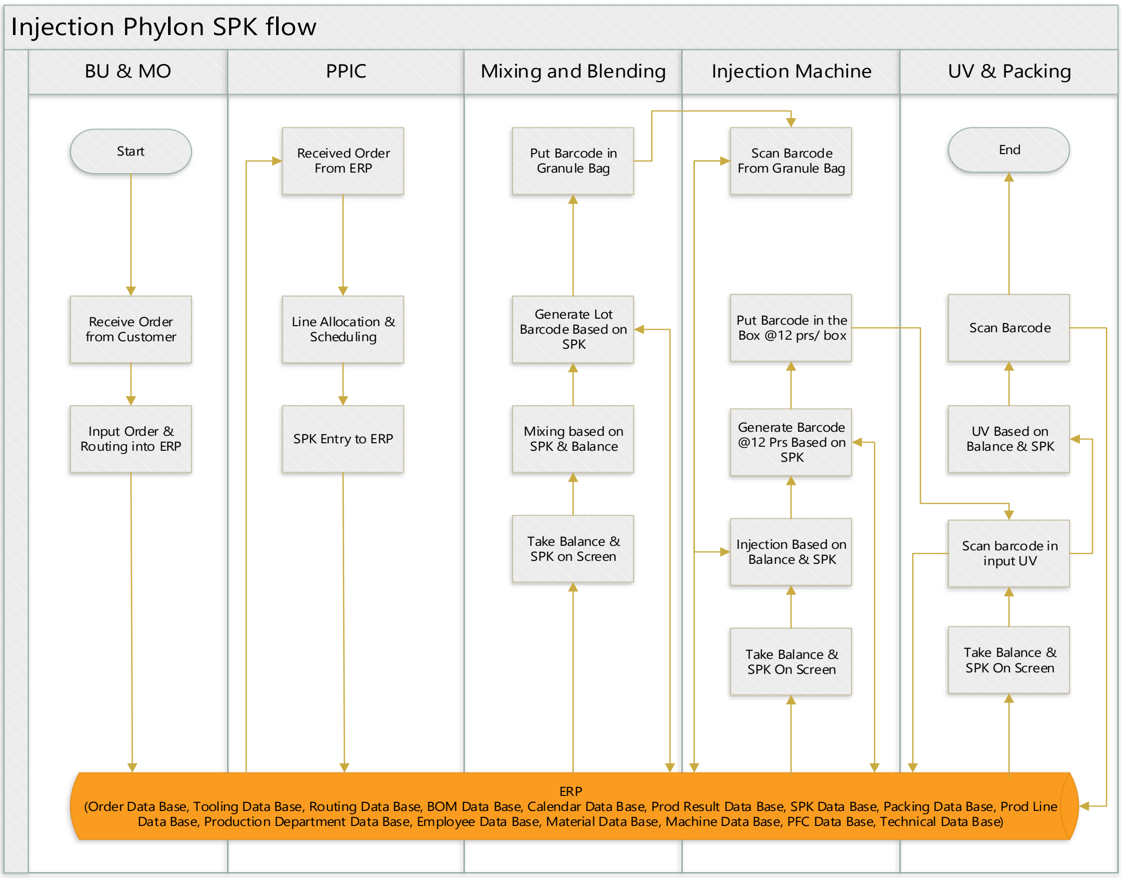


**Figure 5. DSS Process Flow Design in ERP**

2. Make barcode as Kanban Production & Transfer

   Purpose: To facilitate identification of parts of the warehouse and subsequent parts to collect from the warehouse. This barcode will be printed by the IP Production section, and will be attached to the production transfer BOX so that this barcode will continue through all the processes it will go through until the stockfit section will combine the barcode with other barcode parts. Barcode process flow could be shown in Figure 6.

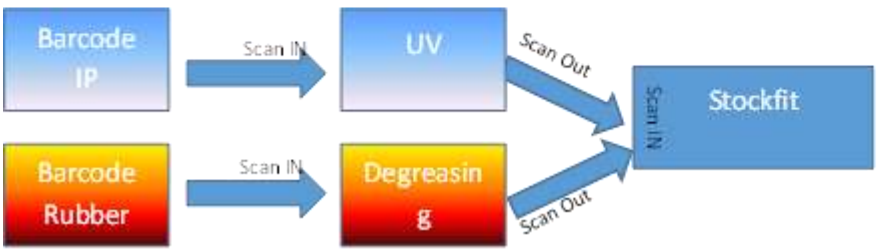


**Figure 6. Barcode Process Flow Design**


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The information in the barcode must provide identification of the Release Week code, Model Name, Style Number/Color Code, Gender, Size, Component name, production line, and SPK date. Figure 7 is the design that will be made for barcode.


**Figure 7. Barcode design**

3. Add workstations at the start and end of each line.

Aims to make it easier for employees to monitor production deficiencies and SPK that will be produced every hour and every day in real time. This workstation is also used as a barcode printer in certain parts and as a barcode reader or barcode scanner in the next section.

## 6. CONCLUSION

Comparison of 2 method of productivity calculation can be shown in table 12. There are six month of both calculation has the same rank, those are Jan as rank 1, May as rank 2, June as rank 3, August as rank 12, September as rank 11 and December as rank 7 Based on calculations using the Waste Assessment Model (WAM) and VALSAT methods, the largest waste identification results were obtained using the WAM (Waste Assessment Questionare) and VALSAT (Value Stream Analysis Tools) tools, namely PAM (Process Activity Mapping), it was found that Inventory was critical waste in a series of processes, that storage takes 1500 minutes on the process which is a NVA process at once. This is caused by employees who find it difficult to classify goods according to their SPK. Some of the problems related to the amount of processed inventory are due to the absence of a system for production control, starting with the issuance of manual work orders and identification of finished goods that are not standard and not in accordance with work orders. Making the SPK design in the ERP system which also provides a barcode system will facilitate and cut inventory by 88% in the warehouse section before the UV process.

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