Implementation of value stream mapping to reduce waste in a textile products industry

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Abstract: Wastes in a production line of a bra model in a textile and textile products industry were identified, and this study aims at minimizing them, and by consequence delays in the delivery of products to consumers. The type of waste was identified employing the Waste Assessment Model approach, and the results show that unnecessary motion is the most predominant one. By eliminating and simplifying activities are not value-added, it was possible to accelerate the production time of the model Bra by 3 minutes and increase the average value of line efficiency by 6.17%.

Subjects: Industrial Engineering & Manufacturing; Engineering Management; Production Engineering

Keywords: VSM; WAM; VALSAT; line efficiency

1. Introduction

Primary needs are needs related to maintaining a proper life. This need is basic and must be met by humans. Primary needs consist of clothing, food, and housing. Without food, people will die. Likewise without clothing and housing. Humans will live tormented and susceptible to disease. To meet the needs of clothing, humans need textile products. The need for textiles continues to grow as the number of people in the world grows. This has led to the rapid growth of the textile industry
in many countries, such as Indonesia, China, India and Vietnam. The textile industry in Indonesia is known as the textile and textile product industry (TPT). The TPT industry in Indonesia covers three sectors, namely the upstream, middle, and downstream sectors (Djafri, 2003). The upstream sector includes fiber-making and spinning industries. The middle sector includes spinning, weaving, dyeing/refining, and batik industries. The apparel industry is a downstream sector.

The textile and textile products (TPT) industry is one of the industrial sectors that is quite important in supporting the economy in Central Java Province, and its contribution to the total export value of Central Java Province in 2017 was equal to 42.31% (US 2.53 USD billion) (Badan Pusat Statistik Propinsi Jawa Tengah, 2017). PT. PMJ is one of the textile and textile products (TPT) industries operating in Central Java Province that manufactures underwear for woman. Underwear products produced are as follows: bra, panty, and lingerie. The production system used is make to order. This condition requires companies to fulfill customer orders in a timely manner in order to increase customer satisfaction. Problem that is often experienced by company is in the form of delays in the delivery of products to consumers. Based on observations in the field, delay in product delivery is caused by non-value-added activities at several work stations when producing components of bra products. One approach that can be used to reduce waste is lean manufacturing (Rohani & Zahraee, 2015).

Lean manufacturing is an approach in the Toyota production system called the Toyota Production System (TPS) to determine the type of waste that occurs and minimize the waste in the manufacturing industry. One tool in lean manufacturing that can be used to reduce waste is Value Stream Mapping (VSM). Value Stream Mapping (VSM) is used to identify waste of resources such as time, material, and movement in a manufacturing process (Saraswat et al., 2014). Waste identification in this study uses the Waste Assessment Model (WAM) method. The WAM method has the advantage of using a simple matrix and questionnaire that are quite specific, so that it can show accurate waste weighting (Rawabdeh, 2005). Next, a mapping tool is selected using the Value Stream Analysis Tools (VALSAT) approach to determine the overall activity on the production department, so that it can show what activities include waste and must be removed. VALSAT is not software. VALSAT is used to select the tools that will be used to analyze and identify further waste by weighting the waste, then from that weighting the tool selection is carried out using a matrix.

The purpose of this study is to identify the most dominant waste in the SB45 model Bra production process and provide suggestions for improvements to reduce waste that occurs in the SB45 model Bra production process. The underwear product that is the object of this research study is the SB45 model Bra. With the reason that during the data collection process, PT. PMJ was working on the SB45 model Bra product.

2. Literature review

2.1. The concept of lean

Lean manufacturing is a systematic approach to eliminate waste and transform processes (Alaca & Ceylan, 2011; Hazmi et al., 2012). This is done by identifying and reducing waste with continuous improvement (Alaca & Ceylan, 2011). There are 3 types of activity grouping from a value-added viewpoint, namely Value Added (VA) or value-added activities in the production process, for example, operating activities in the production process. Then Necessary Non Value Added (NNVA) or non-value-added activities are still needed in the production process, for example, inspection activities and material removal. Furthermore, Non Value Added (NVA) or activities that are not needed in the production process, for example, activities such as waiting, searching, and arranging (Hines & Taylor, 2000). Lean can be applied to the manufacturing industry and the service industry.

Research on lean manufacturing has been carried out by several researchers. Goriwondo et al. (2011) with lean manufacturing can reduce waste defects by 20%, unnecessary inventory by 18% and motion by 37%. Suhardi et al. (2016) conducted research in one of the furniture companies in
Indonesia showing that the lean manufacturing company was able to reduce cycle times by 42%. Pramesti et al. (2016) with the mapping Process Activity Mapping (PAM) tool capable of determining which activities cause waste so that it eliminates non-value-added activities using the 5S method. Jeong and Yoon (2016) with the implementation of VSM, the total lead time can be reduced from 20 days to 3 days with a 92% reduction in the overall lead time for the provision of process databases. Standardization is one of the tools that can be applied in the continuous improvement of the organization (Fin et al., 2017; Mlkva et al., 2016). Hasan et al. (2017) use lean manufacturing to reduce waste motion and accelerate lead time by 8% and increase production capacity by 8.8%. Kumar et al. (2017) able to increase productivity and reduce production process cycle time by 48.7% using the Value Stream Mapping (VSM) method. Aflah et al. (2018) can accelerate production lead times in the socks industry by 34, 14% uses the lean manufacturing approach. Ravizar and Rosihin (2018) state that the implementation of lean manufacturing in absorbent production can accelerate the production process from 61 minutes 34 seconds to 58 minutes 47 seconds. The implementation of work standardization was able to increase production by 63.2% and was able to eliminate overtime (Vargas et al., 2019).

2.2. Value stream mapping (VSM)

VSM presents all activities of value added or not value added for carry a product or product group that is use the same resource through the main flow of the raw material until the product is in the hands of consumers (Hines & Rich, 1997). VSM consists of two types, namely the current state map and the future state map. The current state map describes the entire process before the repair is carried out, while the future state map describes the entire process after repairs are made.

2.3. Waste assessment model (WAM)

Waste is something that happens but is not expected because it does not provide value added. Waste is included in non-value-added activities from the customer side (Hines & Taylor, 2000). There are 7 types of waste grouping which is the focus of lean namely waste motion, waste transportation, waste inventory, waste waiting, waste overproduction, waste over processing, and waste defect (Liker & Meier, 2007). All types of waste are interdependent and affect other types of waste. The seven wastes can be grouped into 3 main categories related to man, machine, and material. The man category contains the concepts of motion, waiting, and overproduction. The machine category includes overproduction waste, while the material category includes transportation, inventory, and defects. To calculate the strength of the waste relationship, a questionnaire was developed to measure it. The relationship between wastes is shown in Figure 1.

![Figure 1. The relationship between waste.](image-url)
The identification of critical waste is carried out using the WAM method. WAM is a model developed to simplify the solution of waste problems to identify in eliminating waste (Rawabdeh, 2005). The WAM method is a method that can show the relationship between wastes and show a critical waste rating (Alfiansyah & Kurniati, 2018). The WAM method can minimize expert subjectivity (Alfiansyah & Kurniati, 2018). This model describes the relationship between seven waste (O: Overproduction, P: Processing, I: Inventory, T: Transportation, D: Defects, W: Waiting, and M: Motion). In carrying out the identification process waste in two ways, that is:

2.3.1. Waste relationship matrix (WRM)
WRM was adopted from the framework developed by Rawabdeh (2005). WRM is used as an analysis of the measurement criteria for the relationship between the wastes that occur. WRM is a matrix used to analyze measurement criteria. WRM is a matrix consisting of rows and columns. Each row shows the effect of a particular waste on the other six wastes. Meanwhile, each column shows the waste which is influenced by other wastes. For each relationship, six questions were asked with a scoring guide, which can be seen in Table 1.

The six questions will be asked for each relationship between wastes so that there are a total of 68 questions. The score obtained from the six questions for each relationship between them is then totaled to get the total value for each relationship. The total value is then converted into a symbol of relationship strength (A, E, U, I, O, X) by following the conversion rules shown in Table 2.

The conversion results are then used again to calculate the level of influence of each waste type to other waste types with conversion values A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0. The results

| No. | Question | Answer choice | Score |
|-----|----------|---------------|-------|
| 1   | Did I produce j | a. Always | 4 |
|     |           | b. Sometimes | 2 |
|     |           | c. Rarely   | 0 |
| 2   | What is the relationship between i and j | a. If i increase then j increases | 2 |
|     |           | b. If i increase then j remains | 1 |
|     |           | c. Not necessarily depending on circumstances | 0 |
| 3   | Impact on j because i | a. Appears immediately and clearly | 4 |
|     |           | b. It took time to show up | 2 |
|     |           | c. Doesn't show up often | 0 |
| 4   | Eliminating the impact i against j can be achieved by ... | a. Engineering method | 2 |
|     |           | b. Simple and direct | 1 |
|     |           | c. Instructional solutions | 0 |
| 5   | Impact i on j mainly affects .... | a. Product quality | 1 |
|     |           | b. The productivity of human resources | 1 |
|     |           | c. Lead time | 2 |
|     |           | d. Quality and productivity | 2 |
|     |           | e. Quality and lead time | 2 |
|     |           | f. Productivity and lead time | 2 |
|     |           | g. Quality, productivity and lead time | 4 |
| 6   | How much impact i on j will increase the lead time | a. Very high | 4 |
|     |           | b. Moderate | 2 |
|     |           | c. Low | 0 |
of this calculation later will be added and the value of the effect level will be known, which is written in percentage units. From the letter symbols obtained, a waste relationship matrix is created which shown in Table 3.

2.3.2. Waste assessment questionnaire (WAQ)
WAQ is designed to identify and allocate waste that occurs in the production line (Rawabdeh, 2005). This assessment questionnaire consists of 68 different questions, which this questionnaire was introduced to determine waste. Each questionnaire question represents an activity, a condition, or a characteristic that may cause a certain type of waste.

Some questions are marked with the words “From”, meaning that the questions explain the types of waste that exist today that can trigger the emergence of other types of waste based on WRM. Other questions are marked with the words “To”, meaning that the question explains each type of waste that is currently available can occur because it is influenced by other types of waste.

2.4. Value stream analysis tools (VALSAT)
Value Stream Analysis Tools (VALSAT) is an approach used for the selection of mapping tools based on the conversion of questionnaire scores results into the matrix (Hines & Rich, 1997). Details of the mapping tools can determine the cause of waste. There are seven kinds of details mapping tools that are most commonly used, as follows:

2.4.1. Process activity mapping (PAM)
This tool is used to identify lead time and productivity, both physical product flow and information flow, not only within the scope of the company and also in other areas in the supply chain. The basic concept of this tool is to map every activity stage that occurs starting from operations, transportation, inspection, delay, and storage, then group them into existing types of activities starting from value-added activities (VA), necessary but non-value added activities (NNVA), and non-value-added activities (NVA).

| Table 2. Conversion of scores to the WRM letters symbol |
|----------------|------------------|------------------|
| **Range**      | **Kind of relationship** | **Symbol** |
| 17-20          | Absolutely necessary | A         |
| 9-12           | Especially important  | E         |
| 5-8            | Important            | I         |
| 1-4            | Unimportant          | U         |
| 0              | No relation          | X         |

| Table 3. Waste relationship matrix (WRM) |
|----------------|------------------|------------------|
| From/To        | O | I | D | M | T | P | W   |
| O              | A | E | O | I | O | X | O  |
| I              | I | A | O | E | I | X | X  |
| D              | O | O | A | E | I | X | E  |
| M              | X | E | A | A | X | I | E  |
| T              | U | O | I | A | X | O | I  |
| P              | O | U | I | I | X | A | I  |
| W              | U | I | I | X | X | X | A  |
2.4.2. **Supply chain response matrix (SCRM)**
SCRM is a graph depicting the relationship between inventory and lead time in the distribution channel so that it can be seen that there is an increase or decrease in inventory levels at distribution time in each supply chain area. From the given function, it can be used as a management consideration to estimate stock requirements if it is linked to achieving a short lead-time.

2.4.3. **Production variety funnel (PVF)**
PVF is a visual mapping technique by mapping the number of product variations at each stage of the manufacturing process. This tool can be used to identify the point where a generic product is processed into several specific products. In addition, this tool can also be used to pinpoint bottleneck areas in process design for planning inventory policy improvements.

2.4.4. **Quality filter mapping (QFM)**
QFM is a tool used to identify the location of quality defect problems in the existing supply chain. This tool can describe 3 types of defects in quality, namely product defects (physical defects of the product) that passed to the customer because they were not successfully selected during the inspection process, scrap defects (defects are still in the internal company so that they were successfully selected in the inspection stage), and service defects (problems felt by customers related to service quality defects).

2.4.5. **Demand amplification mapping (DAM)**
Maps are used to visualize changes in demand along the supply chain. This phenomenon adheres to the low of industrial dynamics, in which demand is transmitted along the supply chain through a series of order and inventory policies that will experience increasing variations in every movement from downstream to upstream. From this information, it can be used in decision-making and further analysis, both to anticipate changes in demand, to manage fluctuations, and to evaluate inventory policies.

2.4.6. **Decision point analysis (DPA)**
DPA shows a wide selection of different production systems, with a trade-off between the lead-time of each option and the level of inventory required to cover during the lead-time process. Decision point analysis is a point in the supply chain where actual demand provides an opportunity to forecast driven push.

2.4.7. **Physical structure (PS)**
It is a tool used to understand supply chain conditions on the production floor. This is necessary to understand the conditions of the industry, how it operates, and to direct attention to areas that may not have received sufficient attention for development.

3. **Research methodology**
This research was conducted through the following stages:

3.1. **Data collection**
This study uses two kinds of data, namely: primary data and secondary data. Primary data includes production process flow, cycle time, waste weighting questionnaire, and the number of operators and machines. Secondary data includes general company data, production amount data, and bill of material.

Production process flow, the number of operators, and the number of machines were obtained by direct observation on the production floor of the SB45 Bra model. Production cycle time data were obtained by measuring the production process cycle time of the SB45 Bra model using the stopwatch measuring instrument. Measurement of the production process cycle time is carried out as many as 30 measurements.
Waste weighting questionnaire is obtained by means of discussion/interviews and distributing weighting questionnaires to parties involved in the production process of the SB45 Bra model. The discussion was conducted to unify perceptions about understanding of waste and the relationship between wastes. Meanwhile, questionnaires were distributed to obtain the weight of the waste.

3.2. Create a current state VSM
The standard time calculation required for map creation on each process category in the value stream. The calculation of standard time is used to find out the time needed to do or complete an activity or work by a reasonable workforce in normal situations and conditions so that general standard time is obtained. The steps for calculating the standard time refer to Lukodono and Ulfa (2017) as follows:

3.2.1. Cycle time (Ws)
Cycle time is the average completion time during measurement. The formula used is as follows:

\[ W_s = \frac{\sum x_i}{N} \]  

where

\[ N: \text{the number of preliminary observations that have been made} \]

\[ X_i: \text{the observed turnaround time during the preliminary measurements that have been taken.} \]

3.2.2. Normal time (Wn)
Normal time is the time the work is completed by workers in reasonable conditions and average ability. The formula used is as follows:

\[ W_n = W_s \times p \]  

where

\[ p: \text{adjustment factor} \]

Assessment of the adjustment factor as follows:

\[ p = 1 \text{ normal working} \]

\[ p>1 \text{ fast working} \]

\[ p<1 \text{ slow working} \]

The Westinghouse method is used to determine the adjustment factor. The Westinghouse system analyses four conditions to determine the rating and the allowance factors: skill, effort, environmental conditions a consistency (Cury & Saraiva, 2018). Thus, the factors are different for each operations of the production line.

3.2.3. Standard time (Ws)
Standard time is the time needed to complete a work cycle carried out according to the normal working method and speed with the consideration of the adjustment factor plus the allowance for personal and other unexpected purposes. The formula is used as follows:
\[ W_b = W_n(l + 1) \]  

where:

\( l \): allowance

Allowance is the time added to normal time to obtain a standard time that is realistic, applicable and achievable. Allowance is given for four things, namely for personal needs, eliminating feelings of fatigue, avoidable delay and unavoidable delay (Lukodono & Ulfa, 2017).

3.2.4. Current state VSM

The next step is to create a current state VSM for the SB45 bra model manufacturing process. Current state VSM or a map with current conditions will make it easier for everyone involved in VSM to understand the conditions/process from the start to the finish. It also makes it easier to know the optimization of the current work process and know where the waste is located. Current state VSM shows 3 interrelated streams, namely: process flow, material flow, and information flow. From here, we will easily identify which area waste is located. At the current state map making stage, direct observations were made and interviews were conducted with operators, supervisors, and production managers.

3.3. Waste assessment model (WAM)

The next step is to identify and measure waste using WAM. In carrying out the waste identification process, two methods were used:

3.3.1. Waste relationship matrix (WRM)

WRM is used to determine the relationship between the existing wastes. The type of relationship at the WRM was then quantified into a numerical scale so that the WRM was obtained for the manufacture of the SB45 Bra model.

3.3.2. Waste assessment questionnaire (WAQ)

WAQ is used to assess what types of waste occur and which is dominant as well as to confirm the findings at the time of observation. The steps used in analyzing the WAQ according to Rawabdeh (2005) are as follows:

(a) Grouping and counting the number of questionnaire questions based on the notes “From” and “To” for each type of waste.

(b) Enter the weight of each question based on the waste relationship matrix.

(c) Eliminates the effect of varying the number of questions for each question type by dividing each weight in a row by the number of questions grouped (\( N_i \)) with the following equation:

\[ S_j = \sum_{k=1}^{K} \frac{W_{j,k}}{N_i}; \text{ for each type of waste } j \]

where:

\( S_j \): score waste

\( W_{j,k} \): weight relationship of each type of waste

\( K \): question number (range 1 to 68)

\( N_i \): number of questions grouped
(a) Calculating the total score ($S_j$) of each column of waste types in Equation (4) and the frequency ($F_j$) of the appearance of the value in each waste column by ignoring the value 0 (zero).

(b) Enter the value of the questionnaire results (1; 0.5; and 0) into each weight of the waste value with the following equation:

$$sj = \sum_{K=1}^{K} \frac{W_j,k}{N_l} \quad \text{for each type of waste } j$$

where:

$s_j$ = the total value of the weight of waste

$X_k$ = the value of the answer to each questionnaire question (1; 0.5; or 0)

(a) Calculating the total score ($S_j$) for each weight value for each waste column and the frequency ($f_j$) for each weight value in the waste column by ignoring the value 0 (zero).

g. Calculate the initial indicator for each waste ($Y_j$) with the following equation:

$$Y_j = \frac{s_j}{S_j} \times \frac{f_j}{F_j} \quad \text{for each type of waste } j$$

where:

$Y_j$ = the initial indication factor of each type of waste

$f_j$ = the frequency of the appearance of values in each waste column regardless of the value 0 (zero) (frequency for $S_j$)

$F_j$ = the frequency of value appearing in each waste column regardless of the value 0 (zero) (frequency for $S_j$)

This indicator is only a number which still does not represent that each type of waste is influenced by other types of waste.

h. Calculating the value of the final waste factor ($Y_{j \text{ final}}$) by entering the probability factor of influence between waste $P_j$ based on the total “from and to” in WRM. Furthermore, to determine the level ranking of each waste by presenting the final waste factor form obtained by the following equation:

$$Y_{j \text{ final}} = Y_j x P_j = \frac{s_j}{S_j} \times \frac{f_j}{F_j} x P_j \quad \text{for each type of waste } j$$

where:

$Y_j \text{ final}$ = the final factor of each type of waste

$P_j$ = probability of influence between types of waste
3.4. **Selection of tools using VALSAT**
After getting the final weighting results from the WAQ, the next step is to choose a VALSAT mapping tool to find out the causes of waste that occurs in the production process of SB45 Bra model by determining activities that include VA, NNVA, and NVA as consideration for improvement.

3.5. **Proposed improvements**
The focus of the proposed improvements is based on analysis from VALSAT.

3.6. **Future state VSM making**
In this stage, a plan for implementing improvement recommendations will be made. This stage also estimating changes in processing time after improvement and drawing the future state map.

4. **Results and discussion**

4.1. **Production process SB45 Bra model**
The sequence of the production process for the SB45 Bra model is shown in the Figure 2.

4.1.1. **Cutting department**
Cutting is the first part of the SB45 Bra model production process which has the main task of cutting materials including allover lace (outer cup), SJ-1043 HEM (wing) fabrics, laminating fabrics (frame), and PN-7426 (inner, side fabrics, neckline). The process of receiving material in the cutting section begins with the process of transferring material from the raw material warehouse. The processes that occur in the cutting department are as follows: 1) spreading process, 2) cutting strap, 3) cutting pattern, 4) material joint.

Spreading is the process of spreading the fabric by spread it, arrange it, and stack the fabrics on the cutting table according to the previously planned amount. The purpose of spreading is to get a pile of fabric that is ready to cut according to the pattern on the marker.
Cutting patterns or the cutting process aims to cut the fabric by following the patterns found on the marking paper so that the cut is obtained according to the planned size pattern. Cutting the strap is the process of cutting and installing the ring slide on the strap, then sewing the strap before entering the sewing department. This aims to save time in the sewing department.

The material joint is the process of providing information or data on clothing components according to their parts after cutting. The material joint process aims to make it easier to distinguish parts of the cloth pieces according to their sizes.

4.1.2. Sewing department
Sewing is the process of assembling raw materials or components for the SB45 Bra model consisting of raw materials, auxiliary materials, and accessories. The raw material that is processed in the sewing is the output of the cutting process, while the output from the sewing process will be the input of the packing process. The sewing process is divided into three stages, namely the cup section sewing process, the wing sewing process, and the cup and wing section assembly process.

4.1.3. Packing department
Packing is the process of packaging and packing finished goods that are ready to be sent to consumers (buyers). The product packaging process consists of EQL inspection, hangtag installation, polybag packing, accuracy inspection, and carton packing.

The finished goods warehouse is a warehouse prepared by the company to store finished goods or the final product. The finished products which have been packaged in the packing department are then stored in the finished goods warehouse. This aims to separate products that are ready to be sent to consumers (buyers) to minimize the possibility of damage or defects.

4.2. Standard time for making SB45 Bra models
The standard time calculation is done to find out the time needed by an operator (who has average skills and is well trained) in carrying out a work activity in normal working conditions and tempo (Wignjosoebroto, 2006). Adjustment values for each activity are obtained from adjustments based on the Westinghouse method obtained from expert adjustment. While the allowance value is given to operators to complete their work activities. Table 4 shows the results of the calculation of the standard time of each workstation.

| No | Workstation                        | Standard time (minute) |
|----|------------------------------------|------------------------|
| 1  | Cutting PN-7426                    | 4.58                   |
| 2  | Cutting Allover Lace                | 4.58                   |
| 3  | Cutting SJ-1043 HEM                | 3.43                   |
| 4  | Cutting Laminating                 | 4.88                   |
| 5  | Joint Material                     | 0.89                   |
| 6  | Cutting Strap                      | 0.76                   |
| 7  | Sewing Cup Part                    | 5.44                   |
| 8  | Sewing Wing Part                   | 1.90                   |
| 9  | Assembly of Cup and Wing Parts     | 5.60                   |
| 10 | Packing                            | 2.34                   |
|    | Total Standard Time                | 34.38                  |
4.3. Current state VSM

Current state VSM, shown in Figure 3, describes the production process of a unit of SB45 bra model. The current state VSM shows the completion of the SB45 bra model took 2062.89 seconds or 34.38 minutes. The time for VA activity is 1495.88 seconds or 24.93 minutes.

The sewing process and the assembling process are sequential processes. Both processes in the current state VSM are not created in one horizontal line. Because both processes are located in one department, namely the sewing department. The assembly process can only be done after the sewing of the cup, wing, and strap components are completed. There is a time to wait for the components needed in the assembly process to be completed.

4.4. Waste identification and measurement

To identify and measure waste in the current state map VSM used by WAM. WAM is done by distributing a seven waste relationship questionnaire to compile a Waste Relationship Matrix (WRM). The process of discussion and filling out the questionnaire involved related parties, namely: PPIC, production, and three people from the Industrial Engineering staff. Furthermore, a questionnaire was distributed consisting of 68 questions to compile a Waste Assessment Questionnaire (WAQ).

4.4.1. Waste relationship matrix (WRM)

WRM is a matrix consisting of rows and columns to show the relationship between each waste (Rawabdeh, 2005). Each row shows the effect of certain waste on the other six types of waste. Each column shows how far certain types of waste are affected by other wastes. The result of the Waste Relationship Matrix (WRM) for the production process of the SB45 bra model is shown in Table 5. The WRM calculation result for the SB45 bra production process is shown in Table 6.

Figure 3. Current state VSM.
Table 5. WRM for the production process of SB45 Bra model

| From/To | O | I | D | M | T | P | W |
|---------|---|---|---|---|---|---|---|
| O       | A | E | D | I | O | X | D |
| I       | I | A | O | E | I | X | X |
| D       | O | D | A | E | I | X | E |
| M       | X | E | A | A | X | I | E |
| T       | U | O | O | 1 | A | X | O |
| P       | O | U | 1 | 1 | X | A | I |
| W       | U | I | 1 | X | X | X | A |

Table 6. Waste matrix value for the production process of SB45 Bra model

| From/To | O | I | D | M | T | P | W | Score | % |
|---------|---|---|---|---|---|---|---|-------|---|
| O       | 10| 8 | 4 | 6 | 4 | 0 | 4 | 36    | 15|
| I       | 6 | 10| 4 | 8 | 6 | 0 | 0 | 34    | 14.2|
| D       | 4 | 4 | 10| 8 | 6 | 0 | 8 | 40    | 16.7|
| M       | 0 | 8 | 10| 10| 0 | 6 | 8 | 42    | 17.5|
| T       | 2 | 4 | 4 | 10| 6 | 0 | 4 | 30    | 12.5|
| P       | 4 | 2 | 6 | 6 | 0 | 10| 6 | 34    | 14.1|
| W       | 2 | 6 | 6 | 0 | 0 | 0 | 10| 24    | 10 |
| Score   | 28| 42| 44| 44| 26| 16| 40| 240   | 100|
| %       | 11.7|17.5|18.3|18.3|10.8|6.7|16.7|100   |

Table 6 shows that waste which has the most influence to cause other waste is from motion with a percentage of 17.5%. While the value to defect and to motion is the type of waste that is most caused by other waste with a percentage of each of 18.3%.

The results of the waste value matrix will be used as the initial weighting value of the WAQ which consists of 68 assessment questions.

4.4.2. Waste assessment questionnaire (WAQ)
The waste value obtained from WRM is then used for the initial WAQ assessment based on the type of question. WAQ has a function to identify and allocate waste that occurs on the production department by distributing questionnaires (Rowabdeh, 2005). The WAQ questionnaire assessment uses three answer scores, namely 1; 0.5 and 0 which are adjusted according to the question category. There are two types of question categories in the WAQ questionnaire, namely category A and category B. For category A, if the answer “yes” is 1, the answer “medium” is 0.5, and the answer “no” is 0. Whereas for category B, if the answer “Yes” is 0, the answer is “medium” is 0.5, and the answer “no” is 1. Measuring waste ranking is done by following these eight steps.

1. Group and count the number of questionnaire questions based on the type of question. Table 7 is the result of grouping and calculating the types of questions.

2. Give weight to each questionnaire question based on the WRM. Table 8 is a summary of the initial weight of the questionnaire.

3. Eliminate the effect of varying the number of questions for each type of question. This is done by dividing each type of question by grouping the type of question (Ni) according to Table 7.
### Table 7. Question type grouping

| No | Kind of question | Total ($N_i$) |
|----|------------------|---------------|
| 1  | From Overproduction | 3             |
| 2  | From Inventory    | 6             |
| 3  | From Defects      | 8             |
| 4  | From Motion       | 11            |
| 5  | From Transportation | 4            |
| 6  | From Process      | 7             |
| 7  | From Waiting      | 8             |
| 8  | To Defects        | 4             |
| 9  | To Motion         | 9             |
| 10 | To Transportation | 3             |
| 11 | To Waiting        | 5             |

Number of questions: 68

### Table 8. The initial weight of the questionnaire questions based on WRM

| No | Aspects of the question | Kind of question | Initial weight for each type of waste |
|----|-------------------------|------------------|--------------------------------------|
|    |                         | O    | I    | D    | M    | T    | P    | W    |
| 1  | Man                     | To Motion      | 6    | 8    | 8    | 10   | 6    | 6    | 0    |
| 2  | From Motion             | 0    | 8    | 10   | 10   | 0    | 6    | 8    |
| 3  | From Defects            | 4    | 4    | 10   | 8    | 6    | 0    | 8    |
| 4  | From Motion             | 0    | 8    | 10   | 10   | 0    | 6    | 8    |
| 5  | From Motion             | 0    | 8    | 10   | 10   | 0    | 6    | 8    |
| 6  | From Defects            | 4    | 4    | 10   | 8    | 6    | 0    | 8    |
| 7  | From Process            | 4    | 2    | 6    | 6    | 0    | 10   | 6    |
|    |                         |      |     |     |     |     |     |     |
| 44 | Method                  | To Transportation | 4    | 4    | 10   | 8    | 6    | 0    | 8    |
| 45 | From Motion             | 0    | 8    | 10   | 10   | 0    | 6    | 8    |
|    |                         |     |     |     |     |     |     |     |
| 66 | From Overproduction     | 10   | 8    | 4    | 6    | 4    | 0    | 4    |
| 67 | From Process            | 4    | 2    | 6    | 6    | 0    | 10   | 6    |
| 68 | From Defects            | 4    | 4    | 10   | 8    | 6    | 0    | 8    |

Total score: 252, 388, 502, 476, 256, 244, 376.
4. Calculate the number of scores (Sj) and the frequency (Fj) of each column of waste types using Equation 4. Table 9 is a summary of question weight after divided by Ni, and the calculation of the Total Score (Sj) and Frequency (Fj).

5. Enter the value of the questionnaire results (1; 0.5 or 0) into each weighted value in the Table 9 by multiplying them.

6. Calculating the total score (sj) and frequency (fj) for each weight value in the waste column. The average questionnaire assessment results are multiplied by the weighted value using Equation 5. The calculation results are shown in Table 10.

7. Calculate the initial indicators for each waste (Yj) using Equation 6. An example of calculating Yj for waste O is shown below.

\[ Yo = \frac{15.83 \times 48}{46.00 \times 57} \]

\[ Yo = 0.29 \]

With the same calculation method, the Yj value is obtained for the other waste, where Yi = 0.27; Yd = 0.23; Ym = 0.23; Yt = 0.28; Yp = 0.18; Yw = 0.19

8. Calculating the value of the final waste factor (Yfinal) by entering the probability factor of influence between types of waste (Pj) based on the total “from” and “to” in the WRM question types with using Equation 7. First calculate the Pj factor. The Pj factor is calculated by multiplying the percentage in the row and column for each waste (Table 6). An example of calculating the Pj factor for waste O is shown below.

\[ Po = 11.7 \times 15 \]
\[ = 175.5 \]

The Pj factor for the other wastes is shown in Table 11.

An example of calculating Yfinal for waste O is shown below.

\[ Yofinal = 0.29 \times 175.5 \]

\[ Yofinal = 50.89 \]

The results of the final waste assessment calculation can be seen in Table 12 below.

The final result of the waste assessment calculation shows that waste that has the highest percentage is motion waste with a percentage of 21.15%.

4.5. **Value stream analysis tools (VALSAT)**

VALSAT is used to identify waste and help find out what strategies the company will use to minimize waste that occurs further in the production department. Table 13 shows the results of the VALSAT mapping tool calculation, whereas Figure 4 shows the ranking of VALSAT.

Based on Figure 4, the tool chosen is PAM, because it has the highest value.
Table 9. Weight of question divided by Ni, total score (Sj) and frequency (Fj)

| No | Aspects of question | Kind of question | Ni | Weight for each type of waste (Wj, k) |
|----|---------------------|------------------|----|-------------------------------------|
|    |                     |                  |    | Wo,k | Wi,k | Wd,k | Wm,k | Wt,k | Wp,k | Ww,k |
| 1  | Man                 | To Motion        | 9  | 0.67 | 0.89 | 0.89 | 1.11 | 0.67 | 0.67 | 0.00 |
| 2  |                     | From Motion      | 11 | 0.00 | 0.73 | 0.91 | 0.91 | 0.00 | 0.55 | 0.73 |
| 3  |                     | From Defects     | 8  | 0.50 | 0.50 | 1.25 | 1.00 | 0.75 | 0.00 | 1.00 |
| 4  |                     | From Motion      | 11 | 0.00 | 0.73 | 0.91 | 0.91 | 0.00 | 0.55 | 0.73 |
| 5  |                     | From Motion      | 11 | 0.00 | 0.73 | 0.91 | 0.91 | 0.00 | 0.55 | 0.73 |
| 6  |                     | From Defects     | 8  | 0.50 | 0.50 | 1.25 | 1.00 | 0.75 | 0.00 | 1.00 |
| 7  |                     | From Process     | 7  | 0.57 | 0.29 | 0.86 | 0.86 | 0.00 | 1.43 | 0.86 |
|    |                     |                  |    |      |      |      |      |      |      |      |
| 44 |                     | To Transportation| 3  | 1.33 | 2.00 | 2.00 | 0.00 | 3.33 | 0.00 | 0.00 |
| 45 |                     | From Motion      | 11 | 0.00 | 0.73 | 0.91 | 0.91 | 0.00 | 0.55 | 0.73 |
|    |                     |                  |    |      |      |      |      |      |      |      |
| 66 |                     | From Over produc-| 3  | 3.33 | 2.67 | 1.33 | 2.00 | 1.33 | 0.00 | 1.33 |
|    |                     | tion            |     |      |      |      |      |      |      |      |
| 67 |                     | From Process     | 7  | 0.57 | 0.29 | 0.86 | 0.86 | 0.00 | 1.43 | 0.86 |
| 68 |                     | From Defects     | 8  | 0.50 | 0.50 | 1.25 | 1.00 | 0.75 | 0.00 | 1.00 |
| Score (Sj) |                  |                 | 46 | 60   | 76   | 72   | 50   | 34   | 56   |
| Frequency (Fj) |                |                 | 57 | 63   | 68   | 57   | 42   | 36   | 50   |
| No | Aspects of question | Kind of question | Average answer | Weight for each type of waste (Wj, k) |
|----|---------------------|-----------------|----------------|-------------------------------------|
|    |                     |                 |                | Wo,k | Wi,k | Wd,k | Wm,k | Wt,k | Wp,k | Ww,k |
| 1  | Man                 | To Motion       | 0.5            | 0.33  | 0.44 | 0.44 | 0.56 | 0.33 | 0.33 | 0.00 |
| 2  |                     | From Motion     | 0              | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3  |                     | From Defects    | 0.6            | 0.30  | 0.30 | 0.75 | 0.60 | 0.45 | 0.00 | 0.60 |
| 4  |                     | From Motion     | 0.2            | 0.00  | 0.15 | 0.18 | 0.18 | 0.00 | 0.11 | 0.15 |
| 5  |                     | From Motion     | 0.1            | 0.00  | 0.07 | 0.09 | 0.09 | 0.00 | 0.05 | 0.07 |
| 6  |                     | From Defects    | 0.3            | 0.15  | 0.15 | 0.38 | 0.30 | 0.23 | 0.00 | 0.30 |
| 7  |                     | From Process    | 0.6            | 0.34  | 0.17 | 0.51 | 0.51 | 0.00 | 0.86 | 0.51 |
| 44 |                     | Method          |                | 0.2   | 0.27 | 0.40 | 0.40 | 0.00 | 0.67 | 0.00 |
| 45 |                     | From Motion     | 0.3            | 0.00  | 0.22 | 0.27 | 0.27 | 0.00 | 0.16 | 0.22 |
| 66 |                     | From Over produc tion | 0.1 | 0.33  | 0.27 | 0.13 | 0.20 | 0.13 | 0.00 | 0.13 |
| 67 |                     | From Process    | 0.3            | 0.17  | 0.09 | 0.26 | 0.26 | 0.00 | 0.43 | 0.26 |
| 68 |                     | From Defects    | 0.4            | 0.20  | 0.20 | 0.50 | 0.40 | 0.30 | 0.00 | 0.40 |
| Score (sj) |                    |                |                | 15.83 | 20.59 | 21.73 | 21.05 | 16.17 | 8.09 | 14.59 |
| Frequency (fj) |                |                |                | 48    | 50    | 54    | 45    | 37    | 27   | 37   |
Table 11. Value of Pj factor

|    | I  | D  | M  | T  | P  | W  |
|----|----|----|----|----|----|----|
| O  | 175.5 | 248.5 | 305.6 | 320.3 | 135 | 94.4 | 167 |

Table 12. Waste assessment calculation results

|    | O  | I  | D  | M  | T  | P  | W  |
|----|----|----|----|----|----|----|----|
| Score (Yj) | 0.29 | 0.27 | 0.23 | 0.23 | 0.28 | 0.18 | 0.19 |
| Pj Factor | 175.5 | 248.5 | 305.6 | 320.3 | 135 | 94.4 | 167 |
| Yj Final | 50.89 | 67.1 | 70.29 | 73.7 | 37.8 | 16.99 | 31.7 |
| The final results (%) | 14.60 | 19.25 | 20.17 | 21.15 | 10.85 | 4.87 | 9.09 |
| Rank | 4 | 3 | 2 | 1 | 5 | 7 | 6 |

4.5.1. Process activity mapping (PAM)

This tool is used to identify all production process activities by determining which activities include VA, NNVA, and NVA for consideration in making improvements. This tool aims to identify the location of waste, eliminate non-value-added activities (NVA), accelerate the process to make it more efficient, and determine the improvements used to reduce the waste. There are five types of activities in PAM namely operation, transportation, inspection, storage, and delay.

Based on the identification of activities with PAM tools, it is known that the overall time for the SB45 Bra model production is 2062.88 seconds or 34.38 minutes with a total of 72 activities in the production process, 59 transportation activities, 4 inspection activities, 1 storage activity, and 18 delay activities. Furthermore, it can be known that working time in VA Activities is 1495.88 seconds, NVA Activities is 160.89 seconds, and NNVA Activities is 406.11 seconds. The PAM result is shown in Table 14–15.

4.6. Proposed improvement

Based on the waste identification result with the Waste Assessment Model (WAM) method and activity mapping with Process Activity Mapping (PAM) tool, it is known that the most common type of waste on the SB45 Bra model production department is waste motion (21.15%). This waste motion will be improved.

Based on the results of mapping activities with PAM and flow production with current state VSM, it is known that there are still 7.80% of NVA with a total time of 160.89 seconds from 1495.88 seconds. Excessive movements that occur on the production department are movements of operators that should not be carried out during the production process such as searching for mold patterns and marker paper, looking for cleaning tools, looking for work tools, arranging products and so on, thus affecting production time that does not add value to the product and process. The causes of motion waste are unfavorable workplace organization, layout, and inconsistent work methods. In this study, the improvement of the production process was carried out by standardizing work, not by improving the work station layout. This is done considering the limited time for research and there are limitations on the part of the company. The company wants to improve the production process without having to change the workstation layout.

The improvement is carried out through standardization of work. Activities that do not provide added value (NVA) must be eliminated from the production process activities. After the improvement, the production process time for the SB45 Bra model become 1882.62 seconds. There is
| Waste            | Score | PAM  | SCRM | PVF  | QFM  | DAM  | DPA  | PS  |
|------------------|-------|------|------|------|------|------|------|-----|
| Over Production  | 14.60 | 14.60| 43.8 | 14.60| 43.8 | 43.8 | 43.8 |
| Inventory        | 19.25 | 57.75| 173.25| 57.75| 173.25| 57.75| 19.25|
| Defect           | 20.17 | 20.17|      |      | 181.53|      |      |
| Motion           | 21.15 | 190.35| 21.15|      |      |      |      |
| Transportation   | 10.85 | 97.65|      |      |      |      | 10.85|
| Inappropriate Process | 4.87  | 43.83|      | 14.61| 4.87 |      | 4.87 |
| Waiting          | 9.09  | 81.81| 81.81| 9.09 |      | 27.27| 27.27|
| Total            | 506.16| 320.01| 81.45| 201  | 244.32| 133.69| 30.1 |
a decrease in the production process time of 180.26 seconds compared to the condition before the improvement. The decrease in production process time is due to 3 reasons. First, NVA activities are eliminated from production process activities. Second, VA activity decreased by 16.84 seconds. Third, NNVA activity decreased by 2.53 seconds. The conditions before improvement and the conditions after improvement are shown in Table 15.

4.7. Future state VSM
Based on the results of the mapping tool analysis with PAM, the next step is the depiction of the future state VSM. The purpose of future state VSM is to find out the differences that occur after improvement with the faster total production time. Reduction in waste of excess motion is done by eliminating unnecessary activities and simplifying activities that take too long in the production process flow of the SB45 Bra model. Figure 5 shows the depiction of future state VSM in the SB45 production process. It is found that the total processing time for the SB45 bra model is 3 minutes faster than before the improvement.

In the initial conditions, it is known that the total production time of the SB45 Bra model starting from raw material entering the cutting workstation until finished goods are finished at the packing workstation is 2062.88 seconds or 34.38 minutes (see Figure 3). Then after standardization, the total working time becomes 1882.62 seconds or 31.38 minutes (see Figure 5)
### Table 15. Condition before and after improvement

| Workstation | Before | | | | After | | | |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|
|             | VA     | NNVA   | NVA    | VA     | NNVA   | NVA    | VA     | NNVA   |
|             | Total  | Time (second) | Total  | Time (second) | Total  | Time (second) | Total  | Time (second) |
| Cutting PN-7426 | 8  | 204.74 | 6  | 41.03 | 3  | 29.09 | 8  | 204.74 | 6  | 41.03 |
| Cutting Allower Lace | 8  | 201.70 | 6  | 41.90 | 3  | 30.36 | 8  | 201.70 | 6  | 41.90 |
| Cutting SJ-1043 HEM | 8  | 130.34 | 6  | 47.34 | 3  | 28.36 | 8  | 130.34 | 6  | 47.34 |
| Cutting Lamating | 8  | 218.06 | 6  | 44.07 | 3  | 30.46 | 8  | 218.06 | 6  | 44.07 |
| Cutting Strap | 5  | 33.52 | 3  | 4.60 | 1  | 7.22 | 5  | 33.52 | 3  | 4.60 |
| Joint Material | 2  | 24.87 | 2  | 28.54 | | | | |
| Sewing Cup Part | 12  | 267.60 | 7  | 31.16 | 3  | 27.42 | 12  | 261.95 | 6  | 28.62 |
| Sewing Wing Part | 5  | 98.70 | 6  | 13.46 | 1  | 1.82 | 5  | 93.08 | 5  | 14.45 |
| Assembly of Cup and Wing Parts | 11  | 239.21 | 15  | 91.05 | 1  | 5.53 | 11  | 233.64 | 13 | 90.07 |
| Packing | 5  | 77.14 | 7  | 62.96 | | | | |
| Total | 72  | 1495.88 | 64  | 406.11 | 18  | 160.89 | 72  | 1479.04 | 60  | 403.58 |
The number of workers in the initial conditions was 54 people (see Figure 3). After standardization of work, the number of workers became 51 people (see Figure 5).

### 4.8. Line efficiency

Line Efficiency is used to show how much the efficiency level of a production line. The higher the line efficiency on a production line, the better the production line. The line efficiency calculation refers to research (Dharmayanti & Marliansyah, 2019).

\[
\text{Line Efficiency} = \frac{\sum_i k S T_i}{K (C T)} \times 100\% \tag{8}
\]

where:

- \(ST_i\): work station time \(i\) (second)
- \(K\): number of work stations/number of workers
- \(CT\): longest cycle time (second)

The results of line efficiency calculations for each workstation are shown in Table 16.

Based on the results of line efficiency calculation, it is known that the average value of line efficiency the SB45 model bra production process after standardization work increased by 6.17%.

The low-efficiency line is due to the large number of workers in the production process of the SB45 bra model. Line efficiency after improvement has increased because the number of workers has decreased compared to before improvement.
Table 16. Results of line efficiency

| No | Workstation                        | Line Efficiency |
|----|------------------------------------|-----------------|
|    |                                    | Before          | After           |
| 1  | Cutting PN-7426                    | 59.80%          | 62.52%          |
| 2  | Cutting Allover Lace               | 58.87%          | 61.72%          |
| 3  | Cutting SJ-1043 HEM                | 59.25%          | 60.61%          |
| 4  | Cutting Laminating                 | 58.65%          | 61.61%          |
| 5  | Joint Material                     | 92.59%          | 92.59%          |
| 6  | Cutting Strap                      | 55.33%          | 71.87%          |
| 7  | Sewing Cup Part                    | 43.78%          | 51.21%          |
| 8  | Sewing Wing Part                   | 57.02%          | 79.83%          |
| 9  | Assembly of Cup and Wing Parts     | 59.91%          | 64.94%          |
| 10 | Packing                            | 67.81%          | 67.81%          |
|    | **Average**                        | **61.30%**      | **67.47%**      |

5. Conclusions

The current state VSM shows the completion of the SB45 Bra model took 2062.89 seconds or 34.38 minutes. The time for Value-Added activity is 1495.88 seconds or 24.93 minutes. Based on the results of identification of waste through questionnaires using the Waste Assessment Model method which consists of two steps, namely Waste Relationship Matrix and Waste Assessment Questionnaire, known types of waste that most often occur on the production department of PT. PMJ is waste motion with a percentage of 21.15%.

After the VSM futures are carried out, the total time for the SB45 Bra production process is 3 minutes faster than before the improvement. In the initial conditions, it was known that the total SB45 Bra production process time was 2062.88 seconds or 34.38 minutes, then after standardizing the total work time the SB45 model Bra production process became 1882.62 seconds or 31.38 minutes. Implementation of VSM in the production process of the SB45 Bra model can reduce waste, as evidenced by a decrease in production time.

The average value of line efficiency the SB45 model Bra production process was originally at 61.30%, then after improvement the work standardization to 67.47%, so that the average value of the SB45 Bra model line production efficiency increased by 6.17%. The low line efficiency is due to the large number of workers who work in the production process of the SB45 Bra model.

The causes of waste of motion are poor workplace arrangements, layout, and inconsistent work methods. In the future, to overcome waste caused by movement, it is necessary to improve in an integrated manner between work standardization and layout improvement.

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