Sustainable-value stream mapping to improve manufacturing sustainability performance: Case study in a natural dye batik SME's

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Abstract. The lean manufacturing system has proved its capability to eliminate waste and produce environmental gains. The integration of sustainable manufacturing indicators in lean manufacturing analysis tools is expected to improve manufacturing sustainability performance. This paper proposes sustainable-value stream mapping to evaluate sustainability performance using a lean manufacturing approach. This new tool will analyze all activities in the manufacturing process incorporated sustainability indicator includes economic, environmental, and social dimensions. The integration of sustainability indicator into a lean manufacturing tool is validated through a mini case study in a small-medium enterprise that produce natural dye batik. The key contribution of the study is a practical framework for identifying non-value-added activities at the production process of natural dye batik. This tool can identify the sources of problems in economic, environmental, and social dimensions. This article can recommend the improvement plan to improve the sustainability performance of a company, especially in batik SMEs.

1. Introduction

Value stream mapping (VSM) is a fundamental lean technique to identify waste and value improvement opportunities. Its purpose is to identify value-adding and non-value-adding activities in the value stream so that wasteful activities can be eliminated, and production can be aligned with demand [1]. Value stream mapping is an effective system analysis for diagnosing manufacturing system problems and identifying improvement opportunities [2] [3]. Both lean and sustainable manufacturing systems aim to improve organizational performance and provide both operational and sustainable benefits. Integrated lean and sustainable implementation can create value for customers by eliminating waste consistently and adopting environmentally friendly, economical and safe processes for employees [4] [5] [6] [7] [8]. The application of Value Stream Mapping [VSM] as a tool to improve the sustainability performance of a production process is still very limited, especially when compared to the large amount of scientific research that focuses on 'traditional' VSM tools [9]. Traditional VSM framework does not account for environmental and societal performance. A number of studies have addressed the extension of VSM to incorporate additional criteria. A vast majority of these efforts have focused on adding environmental and energy-related metrics to VSM. The Sustainable-VSM added environmental and social metrics into VSM to enhance sustainability performance [1], [10] [11]. Previous research has reviewed sustainable-VSM that has been studied in several industrial sectors, including the automotive industry, agricultural food, electronic industry, and wood industry. Sustainable-VSM studies in the textile industry are still very limited, especially in the production process of natural dyeing batik.

The batik industry in Indonesia's mainstay commodity. The batik industry is the largest commodity (18.98%) with a target of increasing sales up to 6-8% in 2019. Coloring process is one of the important elements in creating beautiful batik art [12]. Before synthetic dyes became a trend today, the textile dyeing process used natural dyes. However, as the needs and technological advances increase with the discovery of synthetic dyes for textiles, the use of natural dyes is increasingly eroded. Unlike natural dyes, synthetic dyes will be easier to obtain in the market, guaranteed color availability, various kinds
of colors, and more practical in their use [13]. Related to that, many batik craftsmen who have not treated their waste properly. Washed water that is mixed with chemicals including batik dyes, is just flowed into the gutter or directly into the river [14]. As a result, the river becomes discolored and creates an unpleasant odor. This waste can kill organisms that live in the river.

Bonfante et al [15] explored the opportunities and difficulties of implementing sustainable-VSM in the small and medium enterprises as part of a greening production plan. Bonfante et al found that SMEs have limitations in understanding social and environmental sustainability, even at the management level. SMEs flexibility is noted as driving the adoption of the Sus-VSM. This study aims to apply sustainable-VSM in Batik SME and examines the ability of this tool in order to improve manufacturing sustainability performance.

2. Methodology

2.1. Sustainable-VSM as a tool to enhance manufacturing sustainability performance

The manufacturing sector is a major contributor to the economy, unfortunately, many manufacturing processes have a negative impact on environmental and society. However, the manufacturing process consumes excessive scarce resources and produces hazardous waste and emissions [16]. Efforts to develop sustainability assessment in the manufacturing sector have been carried out before [17] [18]. Simons & Mason [19] proposed Sustainable Value Stream Mapping (SVSM) as a means of increasing sustainability in product manufacturing by analyzing greenhouse gas emissions, CO2, and value-added ratios. Some subsequent studies on the environment-VSM (e-VSM) are still limited by adding environmental indicators to VSM [20]. Sustainable-VSM was developed by Faulkner & Badurdeen [10] to analyzes the economic, environmental, and social dimensions applied to satellite dish manufacturing companies. Indicators analyzed include time, water consumption, materials, and energy, work environment and the physical work of the workforce. Helleno et al [7] propose a conceptual method to integrate a new group of sustainability in indicators into the VSM tool to assess manufacturing processes. The method capability test was conducted in three case studies, and the results showed that the proposed method was able to identify various levels of sustainability of the manufacturing process. Hartini et al [20] designed Sustainable–value stream mapping of the furniture company. Sustainable-VSM is able to identify the potential problems on furniture company. The problems include economic, environmental, and social aspect: high setup time, high defect, high breakdown machine and work in process in almost all processes, high amount of wood waste during sawmill process and energy during oven process and the work posture unergonomic and potential of accident rate still high in sawmill process. If these problems can be reduced the sustainability level will improve [21].

2.2. Manufacturing Sustainability Performance

Sustainable company performance should have three measurement elements, namely: (i) economic, (ii) social, and (iii) environmental. A sustainability indicator is a single parameter used to measure the condition of an aspect in sustainability, namely index [22]. An index can be used to effectively compare sustainability performances over different years for the same production process, which can help decision-makers to evaluate improvement in performance and effectiveness of changes made to the company [18]. An index can be approached by multiplying between the indicator score and its weight [23]. Indicator weights can be approximated by equal weights [24].

2.3. Indicator Scoring

The score of the indicator is determined by using the concept of efficiency, which is the comparison between the use of the sources with an added value toward the total use [23]. The score of the economic indicator is the reflection toward efficiency of time, quality, inventory, and cost. The score of environment indicator is a reflection toward the efficiency of the use of green material, water, material waste, recovered waste. The score of the social indicator is the reflection toward efficiency of workers in terms of health, satisfaction and the development of human resources. The level of work risk uses the level of risk from OHSAS [25]. The indicators that will be involved in evaluating the performance of sustainability and the scoring indicators are summarized in Table 1.
Table 1. The indicator and the indicators and formulas for determining indicator scores.

| Indicator       | Formula                                                   | Reference |
|-----------------|-----------------------------------------------------------|-----------|
| Economic        |                                                           |           |
| Time            | \[\frac{\text{Value added time}}{\text{Cycle time}}\] | [25], [26], [7], [23] |
| Quality         | \[\frac{\text{Number of inputs} - \text{number of rejects}}{\text{Number of inputs}}\] | [23]     |
| Inventory       | \[\frac{\text{Value added time}}{\text{Value added time} + \text{Inventory time}}\] | [23]     |
| Cost            | \[\frac{\text{Value added cost}}{\text{Total cost}}\]   | [26], [23]|
| Green material  | \[\frac{\text{Quantity of green raw material}}{\text{Quantity of raw material}}\] | [7]      |
| Environment     |                                                           |           |
| Water consumption| \[\frac{\text{Ideal amount of water consumption}}{\text{Total amount of water consumption}}\] | [25], [26], [7] |
| Material waste  | \[\frac{\text{Total amount of waste}}{\text{Total amount of input}}\] | [7], [23] |
| Recovered waste | \[\frac{\text{Amount of waste recovered}}{\text{Total waste}}\] | [18]      |
| Social          |                                                           |           |
| Satisfaction    | \[\frac{\text{Number of employees} - \text{number of resign}}{\text{Number of employees}}\] | [25], [23] |
| Health          | \[\frac{\text{Number of employees} - \text{number of absent}}{\text{Number of employees}}\] | [25], [23] |
| Training        | \[\frac{\text{The number of employee who get training}}{\text{Number of employees}}\] | [22], [23] |
| Safety          | \[\frac{\text{Number of employees} - \text{number of accident}}{\text{Number of employees}}\] | [22], [23] |
3. Case study

3.1. Production Process of the Natural Dyeing Batik

The colouring process in batik is an important step in making good quality batik [12]. Before synthetic dyes became a trend today, the textile dyeing process used natural dyes. As the development of synthetic dye technology for textiles, the use of natural dyes for batik production began to decrease. Synthetic dyes are easily accepted by producers because they are easily obtained in the market, guaranteed colour availability, various types of colours, and more practical in their use [13].

The problem arises when batik craftsmen do not process their waste properly. Used rinsing water containing chemicals, including batik dyes, is discharged into waterways or rivers [14]. This causes the river to change colour and smell. The liquid waste can kill organisms that live in the river which have a negative impact on the survival of fish and other animals in it.

To minimize the risks posed by batik waste, the use of natural dyes has again become an alternative choice in batik production. Batik natural dyes can be obtained from plant extracts [27]. These materials can come from roots, stems, bark, leaves, flowers and fruit. From these materials various colours will be produced though not as complete as when using chemical batik dyes [28]. For example, reddish purple staining using mangosteen skin and indigo blue using indigofera tinctoria and mangrove waste. Natural dyes are more environmentally friendly and produce natural classic batik colours. Batik that uses natural dyes has high economic value because it has artistic values and distinctive colours, environmentally friendly so it has an ethnic and exclusive impression [27].

The process of making batik with natural dyes begins with the mordanting process, which is the process of removing starch and fats that stick to the fabric so that the colour can stick well using a solution of metal salts such as alum [29]. Then, the stamping process is carried out. The next process is colouring with natural dyes which usually require two types of dyes. Natural dyes such as mangrove or indigo waste must go through an extraction process. The colouring process is carried out by five times dyeing and drying to get the desired colour intensity. After staining, the fixation process using chemicals such as lime, alum and tunjung. The 'nemboki' process to cover the parts that do not want to follow the next colour using wax that is heated on the stove. The next colouring process uses another colouring material in the same way as the previous colouring and then is fixed. The last process is removing the wax from the fabric called 'nglorod' (washing). The production process of natural dye batik is shown in Figure 1, supplemented by material consumption and non-product output.

3.2. Sustainable VSM of Natural Dyes Batik Production

This research has observed the producing process of natural dyeing batik. Observations were made on all activities from material preparation to product completion. Economic, environmental and social performance is measured at each stage of the process. Economic performance is measured based on efficiency of processing time, level of quality, work in process and production costs. Environmental performance is measured based on the efficiency of Green material, Water consumption, Material waste and Recovered waste. Social performance is measured based on the level of employee satisfaction, health, job risk and resource development through training.
The stamping process has the wasting time for equipment preparation and transportation time to the stamping location. The extraction process is the process of boiling natural dyes for the colouring process. The extraction process still uses firewood, so it requires a long setup time. The colouring is done with 5 times to get the desired colour intensity. Thus, the process of moving from the colouring site to the dying occurs repeatedly. Table 2 is the recapitulation of time efficiency in the economic dimension. The natural dye batik production process has a cycle time of 3889 minutes with a value added time of 3337 minutes, non-value added time of 403 minutes and necessary non value added time of 148.9 minutes. The value of the time efficiency of each process is still below 90% except the extraction process, so these processes must be improved to improve time efficiency. The time of production of batik natural dyes in each process is shown in Table 2.

Batik production process has a good level of quality, rarely found defective products. However, there is still a lot of material waiting to be found that triggers a work in process. Waiting time occurs in almost all processes causing low inventory levels. Factors that influence cost efficiency are the consumption of time and material. The amount of wasting time will be directly proportional to the waste of costs. The comparison between value added costs and non-value-added costs due to time is non-value added is 11% and value added is 89. While the amount of material usage costs is obtained from the price and the amount used in each process. Based on the consumption of time and material, the cost efficiency is still below 90%. The stamping process was 86%, the extraction process was 79%, the colouring process 1 and 2 were 85% and 83%, nemboki 88%, fixation 1 and 2 were 81% and
82% and nglomerod was 86%. This value is considered to still need to be increased so that it becomes a priority for improvement.

### Table 2. Production process time of natural dyeing batik.

| No | Process       | Process time (min) | VA  | NVA | NNVA | Efficiency |
|----|---------------|--------------------|-----|-----|------|------------|
|    |               | O I T D S Total    |     |     |      |            |
| 1  | Stamping      | 347.4 19.1 9.1 10.1 0 385.7 | 317 | 40.4 | 28.1 | 82%        |
| 2  | Extraction    | 372.5 0 1.1 31.9 0 405.5 | 373 | 18.5 | 14.5 | 92%        |
| 3  | Dyeing 1      | 754.8 0 67.3 11.6 0 833.7 | 704 | 75.6 | 53.8 | 84%        |
| 4  | Fixation 1    | 166.1 0 21.6 10.2 0 197.9 | 166 | 31.8 | 0    | 84%        |
| 5  | Waxing        | 617.9 29.1 8.8 39.5 0 695.3 | 618 | 77.4 | 10   | 89%        |
| 6  | Dyeing 2      | 693.3 0 64.6 12 0 769.9 | 641 | 76.6 | 52.5 | 83%        |
| 7  | Fixation 2    | 167.6 0 22.4 20.4 0 210.4 | 180 | 30.8 | 0    | 85%        |
| 8  | Nglomerod     | 338.5 0 29.7 22.2 0 390.4 | 339 | 51.9 | 0    | 87%        |

Total 3458 48.2 225 157.9 0 3889 3337 403 158.9 86%

- Environmental indicator

Raw materials for natural dye batik are grouped into two parts, natural (green) and chemical. Materials used for a batch process are measured and grouped according to this classification. Table 3 is the recapitulation of the green production efficiency. The impact of the material used in the batik production process on the environment shown in Table 4.

### Table 3. The recapitulation of the green production efficiency.

| No | Process       | The number of materials | Efficiency |
|----|---------------|-------------------------|------------|
|    |               | Natural (kg) | Chemical (kg) |         |
| 1  | Stamping      | 0 7 | 0%        |
| 2  | Extraction    | 4 0 | 100%      |
| 3  | Dyeing 1      | 2 0.5 | 80%     |
| 4  | Fixation 1    | 0 2 | 0%        |
| 5  | Waxing        | 0 14 | 0%        |
| 6  | Dyeing 2      | 2 0 | 100%      |
| 7  | Fixation 2    | 0 2 | 0%        |
| 8  | Nglomerod     | 0 0.5 | 0%       |

Efficiency rate 35%

### Table 4. Environmental impact of material.

| No | Materials       | Type   | Impact                                               |
|----|-----------------|--------|------------------------------------------------------|
| 1  | Cloth           | Chemical | The environment will be difficult to decompose the material directly [12] |
| 2  | Colouring:      | Natural | Safe for the environment [12] [28]                  |
|    | Indigo pasta    |         |                                                       |
|    | Mangrove waste  |         |                                                       |
| 3  | Wax             | Chemical | River and soil pollution. Evaporation of a candle can worsen air quality in the work environment [30] |
| 4  | Fixation material | Chemical | River and soil pollution [28]                        |
| 5  | Sodium carbonate | Chemical |                                                       |
| 6  | TRO             | Chemical |                                                       |
The efficiency of water consumption is approached by comparing the amount of water used to ideal water consumption. The ideal amount of water consumption uses references from batik experts. Table 5 is a recapitulation of the water consumption efficiency. Table 6 is the recapitulation of material efficiency and recovered waste efficiency.

**Table 5.** The recapitulation of the water consumption efficiency.

| No | Process | Actual | Ideal | Efficiency |
|----|---------|--------|-------|------------|
| 1  | Stamping| -      | -     | -          |
| 2  | Extraction| 40 litres | 40 litres | 100%        |
| 3  | Dyeing 1| 10 litres | 10 litres | 100%        |
| 4  | Fixation 1| 120 litres | 80 litres | 67%         |
| 5  | Waxing  | -      | -     | -          |
| 6  | Dyeing 2| 10 litres | 10 litres | 100%        |
| 7  | Fixation 2| 130 litres | 80 litres | 62%         |
| 8  | Nglorod | 270 litres | 170 litres | 63%         |

Efficiency 82%

**Table 6.** The recapitulation of material efficiency and recovered waste efficiency.

| No | Process | Material | Material Input | Material Waste | Eff. of material | Recovered | Eff. of recovered |
|----|---------|----------|----------------|----------------|------------------|-----------|------------------|
| 1  | Stamping| Fabric: mori | 20 sheets | 0 | 93% | 0 | 0% |
|    |         | Wax | 7 kg | 0.5 kg | 0 | 0% |
| 2  | Extraction| Indigo pasta | 2 kg | 1 kg | 50% | 0 | 0% |
|    |         | Mangrove waste | 2 kg | 1 kg | 0 | 0% |
|    |         | Water | 40 litres | 20 litres | 0 | 0% |
| 3  | Dyeing 1| Fabric: mori | 20 sheets | 0 | 90% | 0 | 0% |
|    |         | Indigor pasta | 1 kg | 0.1 kg | 0 | 0% |
|    |         | Water | 10 litres | 1 litre | 0 | 0% |
| 4  | Fixation 1| Fabric: mori | 20 sheets | 0 | 25% | 0 | 0% |
|    |         | Fixation material | 1 kg | 0.75 kg | 0 | 0% |
|    |         | Water | 120 litres | 115 litres | 0 | 0% |
| 5  | Nemboki/ Waxing| Fabric: mori | 20 sheets | 0 | 89% | 0 | 0% |
|    |         | Wax | 14 kg | 1.5 kg | 0 | 0% |
| 6  | Dyeing 2| Fabric: mori | 20 sheets | 0 | 90% | 0 | 0% |
|    |         | Mangrove waste | 1 kg | 0.1 kg | 0 | 0% |
|    |         | Water | 10 litres | 1 litre | 0 | 0% |
| 7  | Fixation 2| Fabric: mori | 20 sheets | 0 | 25% | 0 | 0% |
|    |         | Fixation material | 1 kg | 0.75 kg | 0 | 0% |
|    |         | Water | 130 litres | 115 litres | 0 | 0% |
| 8  | Nglorod/Washing| Fabric: mori | 20 sheets | 0 | 40% | 0 | 0% |
|    |         | Hydrogen Peroxide | 0.5 kg | 0.3 kg | 0 | 0% |
|    |         | Water | 270 litres | 255 litres | 0 | 0% |

Efficiency 63% 0%

The amount of recycled waste will determine the level of recovered waste by the company. The recovered waste efficiency is approached by comparing the amount of treated to the total waste produced. The recapitulation of the recovered waste efficiency shown in Table 5. The company has not done the waste treatment properly.

- Social Indicator
The level of employee satisfaction is calculated based on the number of employees who resigned for five years from 2014 - 2019, because it was assumed to be dissatisfied with the work environment, salary, or work system in the company. There is only one employee who resigns the nemboki process so that the efficiency value of the nemboki process is 93% while for other processes 100%. The level of health indicators was obtained from company absence data for the past three years. The health
efficiency in the stamping process and nglorod each by 99% while the other processes respectively by 97%. While the employee training efficiency of all process by 0% because the company has never conducted training for its employees.

The level of the work risk indicator is obtained based on the identification of the type of hazard and the probability of the occurrence of the hazard. In the process of stamping, nemboki and nglorod have H-4 values because this process is in contact with chemicals material that can cause allergies and irritation to the skin. Besides smoke and evaporation at wax can disrupt the respiratory system. The risk of working in the process is classified as moderate but has a high probability. One of the factors causing the high occupational risk is the lack of attention and awareness to use the Self Protection Equipment (SPE). Whereas for other processes it has a low risk because it does not deal with hazardous chemicals so that the probability of occurrence of the hazard is classified as low. However, the level of work risk indicators is a priority for improvement and evaluation because it has a considerable influence on sustainability in batik.

The results of economic, environmental and social performance as pillars in sustainable manufacturing are visualized in sustainable value streams (Figure 2).

![Value Stream Mapping](image)

**Figure 2.** Sustainable-value stream mapping of natural dyeing batik production process.

### 4. Discussion

#### 4.1. The Opportunities and Limitation

Sus-VSM has the opportunity to be applied in SMEs. Sus-VSM is made with clear steps based on the existing production process in the company. Relevant indicators are determined based on factors that have an effect on achieving optimal sustainability performance. That is, companies can achieve economic goals, while being able to protect the environment and be safe and socially comfortable...
based on their limitations. The efficiency approach used to assess sustainability performance requires simple calculations. Based on case studies at batik SME, the application of the Sus-VSM is able to identify and evaluate sustainability performance based on indicators that are relevant to the process of producing natural dye batik. Based on the Sus-VSM, the company can find out the performance that is not optimal based on indicators and activities.

The obstacle that occurs in implementing Sus-VSM lies in the process of measuring the required metrics. Production batch sizes in SMEs are usually small, making it difficult to get normally distributed data. This can be approached by taking data on several batches of production. In addition, SME companies do not have good data records, so almost all data must be based on direct measurements. However, the Sus-VSM can provide information and recommendations to improve sustainability performance.

4.2. Recommendation to Improve Sustainability Performance

Sustainable-value stream mapping is able to identify sources of inefficiency that occur in the production process of natural dyes batik. To improve the company's sustainability performance, this study provides several recommendations as shown in Table 7.

| Indicator       | Process                  | Recommendation                                                                 | Expected improvement |
|-----------------|--------------------------|-------------------------------------------------------------------------------|----------------------|
| Time            | Dyeing, Fixation, Waxing (Nemboki), Washing (Nglorod) | Material handling equipment design to help move from the colouring location to the drying location by adding wheels to the 'gawangan'. *Gawangan* is the designation for a tool used to move cloth after colouring. | Reducing transportation time |
| Recovered waste | Waxing                  | Workplace layout improved using the 5 S principle (*Seiri, Seiton, Seiso, Seiketsu, Shitsuke*) | Reducing setup time |
|                 | Dyeing, Extraction Nglorod | Recovery wax using *gondorukem*. Benchmarks in other companies, recovering wax using *gondorukem* can save wax use by 60%. Wastewater treatment installation | Reducing wax and consumption and improving recovered waste |
| Water consumption | Extraction and dyeing | Use of stop tap and flow meters | Reducing water consumption |
| Work risk       | All process              | Implement standard operation procedures (SOP): use personal protective equipment (PPE) such as filter masks (waxing process) and gloves as well as aprons (all process) | Reducing work risk |
|                 | Waxing (Nemboki)         | The Ergonomic design of work tools such as *gawangan*, chair, stove holder | Reduce the risk of musculoskeletal disorder in the batik body |
| Training        | All process              | Employees are included in training programs, for example about natural dyeing and others | Training has a significant effect on Batik productivity [31] |

Proposed methods for improving sustainability performance are visualized in the future Sus-VSM (Figure 3). The estimation of sustainability performance obtained when applying the proposed method is also informed in the future Sus-VSM. Comparison between current sustainability performance and expected sustainability performance in Table 8.
Table 8. Comparison between current sustainability performance and expected sustainability performance.

| Indicators | Current efficiency | Future efficiency |
|------------|--------------------|-------------------|
| Time       | 86.0               | 90.8              |
| Quality    | 100.0              | 10.0              |
| Inventory  | 64.8               | 64.8              |
| Cost       | 83.8               | 88.4              |
| Green material | 35.0               | 35.0              |
| Water consumption | 82.0               | 90.0              |
| Material waste | 63.0               | 63.0              |
| Recovered waste | 0.0                | 52.5              |
| Satisfaction | 99.1               | 99.1              |
| Health     | 97.5               | 97.5              |
| Training   | 0.0                | 95.9              |
| Safety     | 62.5               | 100.0             |
| Improvement| 64.5               | 81.4              |

Figure 3 The future Sus-VSM.

4.3. Managerial and Theoretical Implications
The basic principle of lean manufacturing is continuous improvement. Value stream mapping is a tool that can identify non-value-added activities that can be used as a basis for making improvements. The design of Sus-VSM in a natural dye batik company has been proven to be able to identify activities that are not yet efficient. Indicators identified include economic, environmental, and social.
dimensions. With the existence of Sus-VSM, companies can understand the types of activities and indicators that need to be improved. In this case, time indicators, waste management, water consumption, and training are still not optimal in almost all activities. This study provides several recommendations that are expected to improve the sustainability performance of batik production.

In terms of theoretical value, this study complements previous research about evaluating sustainability indicators using lean manufacturing tools at the factory level [7] [23] [25]. By considering the relevant indicators in each sector cannot be the same, then designing the Sus-VSM to evaluate the sustainability performance in batik companies enriches the study for the development of theories in the field of measuring sustainability performance.

Batik production with natural dyes has relevance to the use of natural materials and has a lot of water consumption. Key indicators that differentiate it from other sectors, such as furniture companies, are green materials and water consumption. Given the scarcity of previous research on the use of Sus-VSM for evaluating the sustainability performance and relevant indicators in each sector can be different, then evaluating the performance of sustainability in companies in other sectors is interesting for further study. This study only evaluates the manufacturing process. Sustainable manufacturing should consider the overall scope.

5. Conclusion
Sustainable-value stream mapping is able to identify the source of problems that occur in the production process of natural dyeing batik. Inefficient activities occur almost throughout the process. This study provides recommendations by 3R (reduce, reuse and recycle) to improve the efficiency of the economic and environmental dimensions. The reduction is done by reducing the setup time and transportation time by improving the work environment with 5S and the use of material handling equipment. Reuse is done by reusing wax by using gondorukem, thereby reducing material consumption and increasing recovered waste. Recycle is done by treating wastewater so that it increases recovered waste and reduces water consumption. In the end, the reduction of time and material affects the reduction in production costs. The performance of the social dimension is enhanced by improving the work environment, employee awareness in using personal protective equipment and improving training programs.

This research still has not improved all the inefficiencies that have occurred. Further research can be done by designing stamping tools that can reduce processing time and employee risk. The collaboration program with the surrounding community in making natural colouring extracts can reduce the extraction time and add colour variations. The indicator weights used to determine the sustainability index are still assumed to be the same. Further research can be done by evaluating the weight of each indicator by making the expert judgment. Further studies will be more interesting if an evaluation of the sustainability performance of a batik company is carried out by considering a broader scope such as the pre-manufacturing, consumption, and post-consumption stages.

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