The implementation of green lean manufacturing in small scale industry: Reduction energy waste and emission

S A Lintang and Harwati*
Industrial Engineering Department, Universitas Islam Indonesia

*Email: harwati@ui.ac.id

Abstract. This research basically aims to implement green lean manufacturing concept in a small scale industry. A green lean manufacturing is reached by energy saving and emission reduction. Current environmental Value Stream Mapping (VSM) is developed for Batik manufacturing process to identify wastes and bottleneck processes. Traditional process of producing batik raises several problems such as long cycle time and it emerges energy waste, excessive water consumption, emissions from combustion that can damage the environment. Based on all waste that was identified, solutions are suggested to eliminate the energy and emission produced. A future environmental VSM is designed, simulated, and compared with current VSM. The solutions decrease 3.9 of cycle time, 14% of energy consumption, and 63% of emission. This result showed that the solutions are applicable to be implemented in that small scale industry.

1. Introduction
Sentra Batik Ayu Arimbi is one of micro industry that has been established in 2013 which located in Yogyakarta. The company carrying out the traditional batik production process using simple tools and simple process. This simple process of making batik raises several problems such as long processing time and emerge waste in the use of energy, water, materials and produce waste and emissions that can damage the environment [1]. Based on data from the company, there are some complaints that come when the ordered goods are not finished according to the agreed time, there is smoke generated from burning firewood, energy waste such as unnecessary electricity use, waste of water that exceeds 50 liters per piece of cloth where according to Balai Batik Yogyakarta the amount of water that can be used for each piece of batik cloth is 50 liters and the waste produced from the production process has not been maximally processed. From this problem, it can be seen that Sentra Ayu Arimbi Batik has not fulfilled the environmentally friendly batik industry because there is still environmental waste in the production process.

The approach that can be used to eliminate environmental waste and produce the future state value stream mapping is Green Lean Manufacturing approach using Environmental Value Stream Mapping [2]. Green lean manufacturing is a combination of concepts between green manufacturing and lean manufacturing that will produce better performance which will be carried out to cut waste, time, people and supply chains related to the environment. While Value Stream Mapping is a visual representation used to analyze waste that occurs in a production process. Value Stream Map is useful for measuring the current production process at the same time and making a better process in the future. There are two types of Value Stream Mapping, Current State Mapping and Future State Mapping. Current State Mapping is a stream of ongoing production systems that have information to show waste and
improvement. Future State Mapping is the desired improvement in the future. Value Stream Mapping is a tool to overcome improvement from current conditions and propose improvements for future conditions that will cut lead time, production costs and produce timely deliveries without reducing product quality. To produce Value Stream Mapping which has environmental waste, a change was made to conventional Value Stream Mapping to become Environmental Value Stream Mapping by adding energy, water, materials, garbage, transportation and emission factors.

This research is focused on the elimination of environmental waste which can produce the future state value stream mapping in Sentra Batik Ayu Arimbi. The researcher applies Environmental Value Stream Mapping method and Analytical Hierarchy Process to rank the environmental waste. The questions that should be answered in this research is how the recommendation to cut environmental waste in the stamp batik production line Sentra Batik Ayu Arimbi and how is the design of the FEVSM (Future Environmental Value Stream Mapping) on the stamp batik production line Sentra Batik Ayu Arimbi.

2. Method
Environmental Value Stream Mapping (EVSM) is one of the Green Lean Manufacturing methods used to produce the flow of the production process and the flow of information from a product from suppliers to customers in an image or flow [3]. From the Value Stream Mapping (VSM), it can be seen that waste in a company system. Whereas Environmental Value Stream Mapping (EVSM) is carried out by adding environmental factors, namely energy, water, materials, garbage, transportation and emissions [4]. This approach is carried out by having the goal of improving lead times lower. Then calculation of weighting using Analytical Hierarchy Process method aims to decide the most influential factors of interest between waste that occurs [5]. This is done as a recommendation that is prioritized as an improvement that will be made to cut the waste that occurs.

3. Result and Discussion
3.1. Cycle Time
Before the design of Current State Environmental Value Stream Mapping has drawn, the design required process cycle time and environmental waste conditions in the company. The following is a summary of cycle times from the process activity mapping.

| Activity   | Total | Total Time (Second) | Percentage |
|------------|-------|---------------------|------------|
| Operation  | 21    | 69131,453           | 78,91%     |
| Transportation | 9   | 939,588             | 1,07%      |
| Inspection | 4     | 2169,37             | 2,48%      |
| Storage    | 2     | 777,63              | 0,89%      |
| Delay      | 12    | 14586,157           | 16,65%     |
| Total      |       | 87604,198           | 87604,198  |

3.2. Identify environmental waste
After calculating the cycle time for each activity process, calculate the performance of environmental waste in the company is carried out. From the observations made, the company has several environmental waste: water, energy, material, waste and emissions. The following is the calculation of every environmental waste that occurs.
Table 2. Electrical energy used

| Process       | Watt                        | Electrical Used per Batch (hours) | Electrical Energy (Kwh/batch) |
|---------------|-----------------------------|----------------------------------|------------------------------|
| Cutting       | Lamp 25 Watt                | 0.1737                           | 0.0043                       |
| Stamping      | Lamp 25 Watt                | 8.2611                           | 0.2065                       |
|               | Fan 55 Watt                 | 8.2611                           | 0.4544                       |
| Stabbing      | Lamp 25 Watt                | 1.2597                           | 0.0315                       |
| Sealing       | Electric Canting 350 Watt   | 5.5039                           | 1.9264                       |
|               | Lamp 25 Watt                | 5.5441                           | 0.1386                       |
| **Total**     |                             |                                  | 2.7617                       |

Table 3. Result of the emission

| Process     | Energy Used                        | Total of Used | Emission CO2 (KgCO2/batch) |
|-------------|------------------------------------|---------------|-----------------------------|
| Cutting     | Electricity (Lamp)                 | 0.0043 kWh/Batch | 0.0031                     |
| Stamping    | Electricity (Lamp)                 | 0.2065 kWh/Batch | 0.1497                     |
|             | Electricity (Fan)                  | 0.4544 kWh/Batch | 0.3294                     |
| Stabbing    | Gas                                | 0.215 kg/Batch  | 0.6417                     |
| Locking     | Electricity (Lamp)                 | 0.0315 kWh/Batch | 0.0228                     |
| Colouring   | Electricity (Electric Canting)     | 1.9264 kWh/Batch | 1.3966                     |
|             | Electricity (Lamp)                 | 0.1386 kWh/Batch | 0.1005                     |
| Final Inspection | Firewoods                | 3 kg/Batch    | 5.04                        |
| **TOTAL**   |                                    |               | 7.6839                     |

Table 4. Result of the garbage

| Process | Activity                              | Garbage                      | Total     |
|---------|---------------------------------------|------------------------------|-----------|
| Stamping| Stamping Patern                        | Water                        | 0.5 Liter |
| Stabbing| Material Mixing                        | Water, Nitrit, HCL          | 5 Liter   |
| Locking | Washing 1                              | Water                        | 60 Liter  |
| Sealing | Washing 2                              | Water                        | 60 Liter  |
| Colouring| Soaking                               | Water + Detergent           | 10 Liter  |
| Purging | Colour Mixing + Dipping 1             | Water + Indigosol           | 70 Liter  |
| Final Inspection | Colour Mixing + Dipping 2       | Water + Indigosol         | 70 Liter  |
|         | Hot Water Dipping                      | Water + Wax + Baking Soda    | 5 Liter   |
| Packing | Washing 1                              | Water                        | 60 Liter  |
| Cutting | Washing 1                              | Water                        | 60 Liter  |
| Stamping| Washing 2                              | Water                        | 60 Liter  |
| **Total**|                                       |                              | 400.5 liter |
3.3. Current State Environmental Value Stream Mapping

Value Stream at current condition can be mapped in following current State Environmental VSM:

![Figure 1. Current State Environmental Value Stream Mapping](image)

3.4. Analytical hierarchy process

There are so many waste that should be eliminated by industry. Analytical Hierarchy Process (AHP) is used to make its priority [6]. From the results of the AHP calculation, it can be seen that the environmental waste is the company's top priority to be reduced or eliminated are energy and emissions with the final value of 0.39 and 0.32. So that corrective actions will be taken on energy waste and emissions.

3.5. Recommendations

Recommendations are made to reduce the highest environmental waste by using the principle of continuous Kaizen improvement in the entire process. Removal of delay activities in the production process is done to reduce the total cycle time in carrying out the production process. This will have an impact on the reduced electrical energy used and the emissions produced. The following is a calculation of cycle time after kaizen repairs are carried out.

| Activity | Total | Total Time (S) | Percentage |
|----------|-------|----------------|------------|
| Operation | 21    | 69131,453      | 82,11%     |
| Transportation | 9     | 939,588        | 1,12%      |
| Inspection | 4     | 0              | 0,00%      |
| Storage   | 2     | 777,63         | 0,92%      |
| Delay     | 12    | 13345,114      | 15,85%     |
| **Total** | **26** | **84193,785** | **100,00%** |

The recommendation solution to reduce two selected environmental waste is shown in this following table:
### Table 6. Recommendation of Electrical Energy Used

| Process       | Watt               | Initial Electrical Energy (Kwh/batch) | Electrical Cost/kWh (Rupiah) | Initial Electrical Cost (Rupiah) | Recommendation Electrical Energy (Kwh/batch) | Recommendation Electrical Cost (Rupiah) |
|---------------|--------------------|--------------------------------------|-----------------------------|----------------------------------|-----------------------------------------------|----------------------------------------|
| Cutting       | Lamp 25 Watt       | 0.004                                | 1.467,28                    | 6,373                            | 0.0035                                        | 5,147                                  |
| Stamping      | Lamp 25 Watt       | 0.207                                | 1.467,28                    | 303,035                          | 0                                             | 0                                      |
|               | Fan 55 Watt        | 0.454                                | 1.467,28                    | 666,676                          | 0.451                                         | 661,954                                |
| Stabbing      | Lamp 25 Watt       | 0.032                                | 1.467,28                    | 46,209                           | 0                                             | 0                                      |
| Locking       | Electric Canting   | 1.926                                | 1.467,28                    | 2.826,518                        | 1.926                                         | 2.826,518                              |
|               | 350 Watt Lamp 25   | 0.139                                | 1.467,28                    | 203,366                          | 0                                             | 0                                      |
|               | -                  | 0                                    | 1.467,28                    | 0                                | 0                                             | 0                                      |
| Sealing       | Electric Canting   | 1.926                                | 1.467,28                    | 2.826,518                        | 1.926                                         | 2.826,518                              |
|               | Lamp 25 Watt       | 0.139                                | 1.467,28                    | 203,366                          | 0                                             | 0                                      |
|               | -                  | 0                                    | 1.467,28                    | 0                                | 0                                             | 0                                      |
|               | Total              | 2.762                                | 1.467,28                    | 4.052,179                        | 2.381                                         | 3.493,69                               |

The Target of Saving Electricity/Batch: 10%
The Result of Saving Electricity/Batch: 14%
Saving Cost 10 Pcs: Rp558,56
Saving Cost 100 Pcs: Rp5,585,6

### Table 7. Recommendation of Emission

| Process          | Energy Used                  | Total of Used          | Emission CO2 (KgCO2/Batch) | Cost (Rupiah) |
|------------------|------------------------------|------------------------|-----------------------------|---------------|
| Cutting          | Electricity (Lamp)           | 0.0043 kWh/ batch      | 0.0031                      | 6,373         |
|                  | Electricity (Fan)            | 0.4544 kWh/batch       | 0.2696                      | 666,676       |
|                  | Gas                          | 0.215 kg/batch         | 0.6417                      | 1,648,333     |
| Colouring        | Electricity (Electric Canting)| 1,9264 kWh/batch       | 1,3966                      | 2,826,568     |
| Purging          | Electricity (Lamp)           | 0                      | 0                           | 0             |
| Packing          | Gas                          | 0.1783 kg/batch        | 0.5322                      | 1,366,967     |
| Total            |                              |                        | 2.84                        | 6,508,544     |

The Cost Of Replacing Wood With Gas

| Needed           | Cost (IDR) |
|------------------|------------|
| 1 Stove Gas      | 85,000     |
| Gas Cylinders    | 80,000     |
| Regulator Gas    | 55,000     |
| Total            | 226,509    |
| Reduce Emission  | 63%        |
3.6. Future State Environmental Value Stream Mapping

Implementation of solution can be planned to earn new VSM as shown as this following Future State Environmental Value Stream Mapping.

![Future State Environmental Value Stream Mapping](image)

**Figure 2.** Future State Environmental Value Stream Mapping

4. Conclusion

Energy and emissions as environmental waste are prioritized to be eliminated. Energy consumption can be eliminated by applying Process Activity Mapping (PAM) in the production process to result a faster cycle time. From the recommendations for elimination, it was found that the cost savings incurred by the Sentra Batik Ayu Arimbi amounted to IDR 2,192,018 for each batch in saving electricity and replacing firewood with gas. The results of Future State Environmental Value Stream Mapping design are a decrease in cycle time of 3.9% which has an impact on energy consumption which also decreases by 14%. Whereas the emissions released by the batik stamp production process decreased after energy savings and replacement of firewood by 63%.

5. References

[1] Deif, A. M. (2011). A system Model For Green Manufacturing. *Advance in Production Engineering and Management*.

[2] Hines, P., & Rich, N. (1997). The Seven Value Stream Mapping Tools. *International Journal of Operations & Production Management*, 17, 46 – 64.

[3] Wee, H., & Wu., S. (2009). Lean Supply Chain and its Effect on Product Cost and Quality : A Case Study on Ford Motor Company. *Supply Chain Management : An International Journal*, 335-341.

[4] Venkataraman, K., Vijaya, B. R., Muthu, V. K., & Elanchezhian, C. (2014). Application of Value Stream Mapping for Reduction of Cycle Time in a Machining Process. *Procedia Materials Science* 6, 1187-1196

[5] Saaty, T. (1993). *Pengambilan Keputusan Bagi Para Pemimpin*. Jakarta: PT. Pustaka Binaman Pressindo

[6] Padmowati & Delima, R. (2009). Pengukuran Indeks Konsistensi dalam Proses Pengambilan Keputusan Menggunakan Metode AHP. *Seminar Nasional Informatika*. Yogyakarta: UPN Veteran.