Management of Plastic Waste Recycling by Value Stream Mapping

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Abstract. This study explains two recycling process category with plastic pellets and fuel as main products. Fuel can be utilized by vehicles and plastic pellets has economical value. Reduction of waste in plastic waste recycling process was conducted using value stream mapping approach. The research of plastic recycling was done through literature review and direct survey. In first stage, several analyses were made: plastic waste processing category, Value Added Time (VAT) and Non Value Added Time (NVAT), also process time per work station. As the result, current stream mapping was obtained. In the second analysis stage, comparison between two processing category revealed that the highest dissipation came from motion waste, waiting time waste, and movement waste. Big picture mapping was used to improve the quality of waste recycling process based on the procedures that has been established Fore mentioned dissipation can be reduced by adding the number of operator equipped with safety gear in washing and drying.

Keywords: Plastic Waste, Fuel, Plastic Category, Value Steam Mapping

1. Introduction
Plastic as one of the most massive raw material production is a raw material that is relatively cheap, durable, and versatile. This impacts the creation of plastic products that has been beneficial for the society in economics, occupational, and other activities related to quality of life. On the other hand, plastic can impact negatively such as ecological damage. Therefore, various ways are done to decrease the amount of plastic garbage in Indonesia. One of them is to recycled plastics into other product or material. Recycling means is the utilization opportunity of plastics from the waste of consumption in accordance to the form, criteria, and type of the recycling moreover, the priority of plastic waste recycling is to make recycled products that is resemble the original products so its quality does not decrease, for example pellet. So far there’s many factories based in Indonesia that can process plastic waste into pellet [1]. The production has been exported abroad. Four categories of plastic recycling includes: (1) Recycling output known as virgin material or product’s raw material product, (2) Recycling output has no similar characteristic with the original product, (3) Recycling output is in the form of fuel or chemicals such as plastic scraps which become urban waste, (4) Recycling output is in the Form Of Energy, Not Materials [2]. There are various tools and techniques to implement lean principles to industry. Among the various tools of lean, VSM is one of the most important tools in lean manufacture to apply value stream mapping (VSM) for enabling leanness in an Indian camshaft manufacturing organisation. Then Vinodh [3] to explore the practical feasibility of deploying value stream mapping (VSM) for enabling lean manufacturing.
Miya and Ngacho [4] stated that VSM is one of the techniques tool of lean thinking philosophy that can be used to analyze the current state of a process, materials and information flow necessary to bring out products or services to the customer. VSM tool is concerned with finding the best techniques and solutions to reduce or eliminate waste in a process and identify opportunities for improvement. The effective technique of value stream mapping can be used to reduce or eliminate waste in processes of solid waste management, mitigate challenges of SWM and identify opportunities for improvement.

**Tabel 1. Previous Research in Value Stream Mapping**

| No | Author | VSM | Results |
|----|--------|-----|---------|
| 1  | Guilherme Luz Tortorella, Lucila M. S. Campos and Glaucio Garcia Martins Pereira da Silva [5] | VSM, | Considering the five studied RCs, resulting in an increase of 22% in employment opportunities. |
| 2  | Rubiano O. Oscar; Peña M. Claudia C.; Paz R. Juan C. [6] | VSM, | The results confirm some advantages of the proposed VSM methodology as a practical redesign tool of waste and materials flows in the value stream. Policies and legislation are very necessary to plan, design and implement solid waste management operations, however with no enforcement the policies are toothless. |
| 3  | Anne Miya, Christopher Ngacho [4] | VSM, | The result is that the developed tools can analyze problems in economic, environment, and social aspects as the basic of improvement. |
| 4  | Sri Hartini, Udisubakti Ciptomulyono, Maria Anityasari, Sriyanto, Darminto Pudjotomono [7] | VSM, Sustainable concept, Sus-VSM, | Based on the result of the research, there are seven types of production waste: overproduction (9,62%), inventory (17,3%), defect (23,08%), motion (9,62%), transportation (9,62%), Over processing (9,62%) and waiting (21,15%). It is recommended to integrate VSM to other analytical tools able to handle system variation, presenting the dynamics between system components and validating the future state before its real implementation takes place. Computer modelling and simulation may fulfill these requirements and are proposed as future research development towards a more holistic approach to lean system analysis. |
| 5  | Putri Citra Marifa, Feny Yuliana Andriani, Sri Indrawati, Anggita Noviyanti Parmasari, Hardiyanti Budiman, and Atika Kamilia [8] | VSM, VALSAT, QFM | |
| 6  | Guilherme Luz Tortorella, Flávio Sanson Fogliatto, Michel Anzanello, Giuliano Almeida Marodon, Mayara Garcia & Rafael Reis Esteves [9] | VSM, | |

2. **Methods**

The methods consist of five steps. Step one, from this research is to conduct preliminary study regarding plastic factories existing in Indonesia, then continued with factory visiting and chose the two factories for the study case that will be analyzed in this research. Step two, to categorize raw materials and process of plastic waste processing mechanically with two indicators that is plastic recycling [1]. Step three, identify the existing waste processing that is existing today. In this step, it is explained more detail regarding physical and non-physical resource management of both factories. Step four, conduct analysis Value Stream Mapping in both cases with these steps:
- Creating Big Picture Mapping
- Calculating activities time (Value Added & Non Value Added)
- Making and spreading questionnaire
- Conducting VALSAT analysis
- Analysing wastefulness in accordance to the 8 waste rules in Lean Manufacturing

Step five, is to analyse the best practice and give recommendation for plastic waste processing management in accordance to the analysis data in Step Three and Step Four. Research Location: an example of reprocessing pellet into pellet can be seen in the ongoing process in MBG, where pellet is reprocessed into broom handle. AJP factory does not conduct the process. Mechanical recycling process of plastic explains by Fisher in Gabriel [1] proves that the material made of plastic can be recycled into raw material with three categories, and also a quartener recycled product
that does not produce material as an output, but an energy instead. The three mentioned categories can be seen in Figure 1.

![Figure 1. Categories of Material Produces from Recycled Plastic Waste](image)

### 3. Result and Discussion

*Value Stream Mapping* (VSM) shows details of material flow, operational lead time, yield, uptime, human resource needed, frequencies of delivery, inventories, inventories amount, batch size, setup time, process time, and holistic efficiency of process. Through this method, general analysis will be conducted against the waste from the process of the plastic waste treatment/production in MBG and AJP with a few steps such as, sorting, weighing, grinding, cleansing, drying, packaging, and or reprocess the plastic waste into goods. During the process of production with unsophisticated tools and little man power, there has been a few wastes in both factory. One example is when the grinding process. There is motion waste which is the repeating movements of hands and feet to push raw material into the machine until the raw material is run out or the grinding process is done. Through visits to both factories, it is known that the outline of the plastic waste processing mechanism in both factories is quite similar with the process that is defined by Manrich and Santos. Below is the identification results:

#### Table 2. Plastic Waste Processing Mechanism in Factory Category 1 and 3.

| Steps of Mechanical Recycling | Case study: Factory Category 1 | Case study: Factory Category 3 |
|------------------------------|--------------------------------|--------------------------------|
| **Stage 1:** Identification, separation, and sorting plastic raw material | Manually will be sorted by 10 female worker, seperated by waste types, cleansed with water and put in a plastic sack of 1 ton | There is no specific sorting process. There is not much plastic that is not uniform because it has been sorted by suppliers since the delivery of the raw materials. |
| **Stage 2:** Grinding | One male worker will put raw materials into grinding pipes. After the raw materials is put into the tip of the pipe, worker will press it with foot so the raw material enters the 0.5 m diameter grinding pipes | There are 2-3 male worker put the uniform PE or PP raw material gradually into the grinding machine/ When putting the raw materials, worker will separate dirt or a not uniform plastic aside. The grinding machine capacity is up to 1 ton. |
| **Stage 3:** Cleansing, with or without additional cleansing product | The grinded plastic in each colors enters the gravity pipes. Gravity pipes is connected to the water channel that consist of cleansing soap and alum. The waste grindin result will be taken by cleansing water flow through pipes and enters the shelter section to be put into the plastic filter manually. The larger grinded product that is larger than the diameters of the | The grinded plastic falls into the hole below the machine and pushed by conveyor that connects the grinding machine with the cleansing pool. The cleansing pool is filled with water that is constantly moved with a waterwheel so plastic will be pushed forward. The capacity of the cleansing pool is up to 1 ton. |

1st recycle

- Output material had similar characteristics with original or virgin material

2nd recycle

- Material output had different characteristics from virgin material

3rd recycle

- Process output produced scrap in the form of chemicals that can be used fuel

4th recycle

- New source of energy
Table 2. Plastic Waste Processing Mechanism in Factory Category 1 and 3.

| Steps of Mechanical Recycling | Case study: Factory Category 1 | Case study: Factory Category 3 |
|-------------------------------|-------------------------------|-------------------------------|
| filter holes is put into clean water, while the smaller one is outcasted to reach the final disposal channel. | The grinded plastic is carried away by the pool water into the conveyor that bring the grinded plastic into the drying machine. | The grinded plastic is carried away by the pool water into the conveyor that bring the grinded plastic into the drying machine. |
| Stage 4: Drying | The clean plastic waste will be sheltered in the filter and put into the drying machine. The machine capacity is up to 3 drying baskets (approximately 7 kg). The machine will be closed and drying process will take for 20-25 minutes. | The drying cubicle is 1x 1.5 m big with 2 m height. There are 2 drying cubicle that is sometimes supervised by 1 person to ensure that the dry plastic has been sucked by vacuum. |
| Stage 5: Silos | - | The grinded plastic that has been dried is sucked by a long vacuum through the storage room near the printing machine. One operator will help the dry grinded plastic to enter the machine by a little push with a wood. |
| Stage 6: | - | High temperature machines will process the plastic into solid chunks |
| Agglutination | - | Plastic chunks is printed into plastic noodles |
| Stage 7: | - | Plastic noodles is distributed to cold water and cut in the form of small seed pieces |
| Extrusion | - | |
| Step 8: | - | |
| Granulation | - | |

Analysis of Stream Mapping after conducting Value Added Tools (VAT) and Non Value Added Tools (NVAT) for waste management

3.1. Case Study: Factory category 1 (MBG).
Identification of Plastic Waste Category that is used by MBG: Plastic waste categories used by MBG can be seen in Table 3. below,

Table 3. Identification of Plastic Waste Category in Factory Category 1 (MBG).

| Waste Management | Output | Cause of Material Degradation |
|------------------|--------|-------------------------------|
| Mechanical Recycling Process | Residual value medium: all brands of bottle packaged drink (transparent, blue, green), soya sauce bottle, sauce, etc. | Recycled plastic pellets | Processing of plastic waste into grinded plastic pellets |
| | Residual value medium: all brands of glass packaged drink | | Processing of plastic waste into plastic pellets |
| | Residual value low: infusion bottle waste, drinking gallon cap waste | | Processing of plastic waste into alternative fuel |
Table 4. Analysis of VAT and NVAT For Process in Factory Category 1 (MBG).

| Process Type | Cycle Time (s) | Lead Time (s) |
|--------------|---------------|---------------|
| VAT          | NVAT          |
| Transporting | 180           | 1980          |
| Grinding     | 1260          | 1286          |
| Cleansing    | (a) Grinded material is washed with alum water
|              | (b) Grinded material is stored in the filter and moved into a clean water basin
|              | (c) Grinded material is washed with clean water manually
|              | (d) Grinded material is stored in a filter and put into drying machine
|              | (e) Separation of objects carried by the grinded materials
|              | (f) Waste is distributed to the back of the factory |
| Drying       | 1286          |
| Packing      | (a) *Flakes* are put into sacks
|              | (b) Products are exported to Hongkong & China |

| Total (s)    | 4908          |

Resume of process time per work station Factory category 1 (minutes).

| Transporting | Chopping | Cleansing | Drying | Packing | Leadtime |
|--------------|----------|-----------|--------|---------|----------|
| 3 minutes    | 33 minutes | 21 minutes | 21 minutes | 6 minutes | 84.8 minutes |

Resume shows that Lead Time for 10 kg of raw materials are 84.8 minutes. It means that every once in 1 hour and 28.8 minutes, a 10 kg plastic waste raw material are completely processed. Lead time for 10 kg per unit can be approached by above calculation. After knowing activities that includes in VA or NVA, a big picture mapping (Figure 2) can be shown as below

Figure 2. Value Stream Mapping in Category 1 Thermoplastic Recycling System

Analysis: Through observation, the most dominant waste is unnecessary motion, waiting, and excessive transportation. By doing re-crosschecking towards types of the most dominant waste regarding to the waste management executor (owner) by using 7 waste questionnaire by interview. Below is the recapitulation of 7 waste for Factory Category 1 – MBG
Table 5. The Difference in Analysis of The Most Dominant Waste MBG (Questionnaire).

| Score | Over production | Waiting | Excessive transportation | Inappropriate processing | Unnecessary inventory | Unnecessary motion | Defect |
|-------|-----------------|---------|--------------------------|--------------------------|----------------------|-------------------|--------|
| Total value | 1 | 1 | 4 | 2 | 3 | 3 | 0 |

Therefore, the comparisons of the most dominant waste type based on researcher and owner is as below,

Table 6. Comparison of Dominant Waste Between Owner and Researcher

| Researcher | Unnecessary Motion | Waiting |
|------------|---------------------|---------|
| Owner      | Unnecessary Motion  | Unnecessary Inventory |
| Root cause | Bad workplace organization and layout, inconsistent work method, and machines with bad design | Waiting: The length of duration in product changing and inconsistent work method |
|            | Unnecessary inventory: Unbalanced workflow, bad tools, inaccurate production forecast, incapable vendors, batch size that no big enough and the length of duration in product changing |

There are differences between identification according to researcher’s observation and owner’s questionnaire result which are in waiting and unnecessary inventory aspects. Both aspects will become an evaluation for integrated plastic waste management. By using Seven Value Stream Mapping Tools, it is obtained a VALSAT recapitulation as below:

Table 7. VALSAT Recapitulation MBG.

| Waste          | Process Activity Mapping | Supply Chain Response Matrix | Production Variety Funnel | Quality Filter Mapping | Demand Amplification Mapping | Decision Point Analysis | Physical Structure |
|----------------|--------------------------|------------------------------|---------------------------|------------------------|-------------------------------|-------------------------|--------------------|
| Over Production| 1                        | 2                            | 1                         | 3                      | 3                             | 3                       | (44.84%)            |
| Waiting        | 9                        | 9                            | 1                         | 3                      | 3                             | 3                       |                    |
| Transport      | 36                       |                               |                           |                        |                               |                         | 1                  |
| Inappropriate processing | 18                      | 6                            | 2                         |                        |                               | 2                       |                    |
| Unnecessary Inventory | 9                       | 27                           | 9                         | 27                     | 9                             | 3                       |                    |
| Unnecessary Motion | 27                      | 3                            |                           |                        |                               |                         |                    |
| Defect         | 0                        |                               |                           |                        |                               |                         | 9                  |
| Total          | 100                      | 41                           | 16                        | 12                     | 33                            | 17                      | (7.62%)            |
| Total %        | (44.84%)                 | (18.38%)                     | (7.17%)                   | (5.38%)                | (14.79%)                      | (7.62%)                 | (1.79%)            |
| Ranking        | 1                        | 2                            | 5                         | 6                      | 3                             | 4                       | 7                  |
Figure 3. Value Stream Mapping in Category 3 Thermoplastic Recycling System

3.2. Case study: Factory Category 3.

Waste management 2: Below is the result of 7 waste questionnaire recapitulation for Factory Category 3. Based on 7 Waste Questionnaire evaluation, it can be understood that by lean there are no significant waste for AJP. There is also a difference in the most dominant waste evaluation between researcher and owner.

Table 8. Difference of Analysis Result in Most Dominant Waste Factory Category 3 (AJP).

| Recapitulation | Over production | Waiting | Excessive transportation | Inappropriate processing | Unnecessary inventory | Unnecessary motion | Defect |
|----------------|-----------------|---------|--------------------------|--------------------------|-----------------------|-------------------|--------|
| Score Total value | 0 | 1 | 0 | 0 | 0 | 1 | 1 |

| Researcher Owner | Unnecessary Motion | Waiting | Excessive Transportation |
|------------------|--------------------|---------|--------------------------|
| Unnecessary Motion | Bad workplace organization and layout, inconsistent work method, and machines with bad design |
| Unnecessary Motion | Waiting |
| Root cause | The length of duration in product changing and inconsistent work method |

| Owner | Defect |
|-------|--------|
| Excessive transportation: Bad factory layout, no team coordination, bad factory maintenance, not suitable factory organization, and too many warehouses that is too far. Defect: Error in process, ineffective training, and no standard procedures. |

Table 9. Recapitulation of VALSAT Calculation for Factory Category 3.

| Waste          | Process Activity Mapping | Supply Chain Response Matrix | Production Variety Funnel | Quality Filter Mapping | Demand Amplification Mapping | Decision Point Analysis | Physical Structure |
|----------------|--------------------------|-----------------------------|---------------------------|------------------------|-----------------------------|-------------------------|-------------------|
| Over Production Waiting Transport Inappropriate processing Unnecessary Inventory Unnecessary Motion Defect | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total            | (42.2%)                  | (22.2%)                     | (2.2%)                    | (20%)                  | (0.03%)                    | (0.03%)                    | (0%) |
| Ranking          | 1                        | 2                           | 5                         | 3                      | 4                           | 4                        | 6                 |
4. Conclusion
In the Big mapping of plastic waste management process flow factory Category 1, the main waste that happens in managing plastic pellets are motion and waiting. The problem in transportation can’t be deeply reviewed because the factory layout is prioritized for raw material hoarding and the grinding process is conducted in series. Improvement recommendation in waste that happens in the production process of plastic pellets are to add new tools whether for cleanser or dryer and to improve machines flow so that it follow the gravity direction. The plastic waste management in factory category 3, the main waste happens in unnecessary motion, waiting, excessive transportation and defect. Improvements can be done by putting raw materials in accordance to the capacity of machines periodically so that there is no delay in waste management process that is linear to the management cost. Improvement of management process in factory layouts is that it needs a raw material excess flow that later will be processed into oil fuel and plastic pellets in parallel. This is supposed to save space, cost, energy and can increase the revenue of plastic waste entrepreneur.

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