The Effort to Increase Waste Reduction Through the Development of Waste Banks in South Surabaya

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Abstract. Waste bank is one of the government’s efforts in reducing inorganic waste going to landfills by involving the role of the community in sorting out waste. In 2016, Surabaya had 240 waste bank units. The effort to reduce waste through waste banks in Surabaya was still relatively small at 0.55 tonnes/day. Waste reduction through waste bank needed to be improved so as to reduce the load of garbage accumulation in the landfill site. Currently, South Surabaya has 60 waste banks, though only very few of those waste bank units are still operating. This research was conducted to determine the potential for waste reduction that could be done through the development of waste banks in South Surabaya. The STELLA 9.1.3 dynamic program was used to predict the potential waste reduction through the development of waste banks in the next 10 years.

Keywords: community participation, system dynamic, waste bank

1. Introduction

South Surabaya is an area with the second largest population in Surabaya with 764,331 people. The amount of waste generation in South Surabaya is 738,114.45 kg/day in which 425,667.90 kg/day is the amount of waste transported to the landfill site [1]. Waste bank is a solution in dealing with urban waste that involves the community in managing their environment [2]. Waste bank has a management concept of collecting recyclable waste and has management like a bank, where waste collected is weighed and valued with a sum of money [3]. In addition to encouraging economic empowerment of the local community, waste bank also teaches the community to sort out their own waste so it is expected to reduce waste generation entering the landfill site [4].

Currently, South Surabaya has 60 waste bank units in each sub-district with a total of 11,240 customers [5]. However, only very few waste bank units are active in carrying out waste weighing activities. The lack of the community participation is one of the causes of the inactiveness of a waste bank unit, which causes the small amount of waste reduction through a waste bank. This study aimed to get predictions on the potential for waste reduction through waste banks in the next 10 years using the STELLA 9.1.3 dynamic program.

2. Materials and Methods

This research was started by collecting secondary data and primary data. The secondary data were the population data of South Surabaya, amount of waste generated by the community in South Surabaya,
the number of waste banks in South Surabaya, and a map of South Surabaya. The primary data were obtained by making observations directly in the field. Observations were made to obtain existing data on waste banks in South Surabaya, generation data and waste composition that entered the waste banks in 2018. Data collection of waste and waste composition were carried out at 37 waste banks spread across 8 sub-districts in South Surabaya.

The secondary data and the primary data were processed using the STELLA 9.1.3 dynamic program to predict the potential waste reduction through waste banks by observing the amount of the waste generation, the composition of the waste and the number of customers. System dynamic models were chosen because they can describe dynamic system behavior in accordance with time [6]. The data were processed through several stages: (1) the formulation of dynamic models (making causal loops); (2) the running of the model; (3) the prediction simulation.

3. Results and Conclusions

The sampling locations of the waste banks are shown in Figure 1, consisting of 37 units of waste bank. The collection and weighing of waste at the waste banks studied were generally done once a month, but there were several waste banks that weighed waste every week or every two months. The average amount of waste generation that was reduced by waste banks in 2018 was 6946.48 kg/month with the composition of paper waste amounting to 3311.59 kg/month (48%), plastics 1777.41 kg/month (26%), glasses 779.31 kg/month (11%), iron 451.21 kg/month (6%), aluminum 116.12 kg/month (2%), and other waste 510.85 kg/month (7%).

Before making the model, it was necessary to know several factors that would influence the potential of waste reduction through development of a waste bank, thus a Causal loop diagram was needed (Fig.2). A causal loop diagram became the basis of the thinking framework in making a scheme model (Fig. 3) of the development of a waste bank.

A causal loop diagram shows the relevance of each variable showing cause and effect. Cause and effect relationships are indicated by the direction of arrows that either marked positive or negative. A positive sign shows a relationship is directly proportional between variables, while a negative sign shows a relationship is inversely proportional. In Figure 2, it can be seen that the population affects the amount of waste generation, thus with an increasing number of population, the resulting waste generation would also increase, and vice versa. When sorting waste, it was divided into organic waste, inorganic waste, and mixed and other waste. Sorting increases the amount of separated organic waste and inorganic waste and reduces the amount of mixed and other waste that cannot be utilized.

Figure 3 is a scheme model that makes it easier to describe scenario modeling. The total weight of inorganic waste processing at a waste bank was stocked, which was influenced by the flow from the increase in weight of inorganic waste and would affect the value of the converter of each type of inorganic composition in the waste bank. Waste weight per type can be seen from the relation of arrows from total weight of inorganic waste in the waste bank with the percentage of composition per type of waste. The definitions of each variable in the model scheme are presented in Table 1.
Figure 1. The Sampling Locations of Waste Bank

Figure 2. Causal Loop Diagram
Figure 3. Scheme Model

Table 1. The definition of each variable in the scheme model condition

| Name of variable                                    | Definition                                                      | Unit       |
|-----------------------------------------------------|-----------------------------------------------------------------|------------|
| Existing condition of reduction in waste bank       | Total waste reduction in waste bank                             | tonnes/year |
| Existing condition of paper waste reduction in waste bank | Paper waste reduction in the waste bank                         | tonnes/year |
| Composition of paper waste                          | Mass of paper waste                                             | tonnes/year |
| Existing condition of PF paper                      | Percentage of waste bank customers from population in South Surabaya | %          |
| Rate of increase of PF paper waste                  | The increase of percentage in the community participation of waste bank activity | %          |
| RF paper existing                                   | Percentage of recovery factor of paper waste in existing condition | %          |
| Rate of increase of RF paper waste                  | The increase of the percentage of recovery factor of paper waste in waste bank activity | %          |
| Existing condition of reduction in composting       | Total waste reduction in composting activities                  | ton/year   |
| Composition of organic waste                        | Mass of organic waste                                           | ton/year   |
| Existing condition of PF organic waste              | Percentage of population who make composting from the population in South Surabaya | %          |
| Rate of increase of PF unidentified waste           | The increase of percentage in the community participation of composting | %          |
### Name of variable | Definition | Unit
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RF of organic waste in existing condition | Percentage recovery factor of organic waste in existing condition | %
Rate of increase of RF organic waste | The increase of percentage recovery factor of organic waste in waste bank activity | %
Total of waste reduction in existing condition | Addition of waste reduction in waste bank and composter | ton/year
Total mass of waste | Total mass of waste | ton/year
Existing condition of mass waste in landfill | Mass waste in landfill existing condition | ton/year

#### 3.1 Scenario existing condition (the 1st scenario)

In this scenario the model scheme is determined from the existing conditions of waste reduction through waste bank and composting in South Surabaya. Variables included in model scheme are based on field analysis. The 1st scenario shows that the total waste reduction is the amount of waste reduction in waste bank and composter. Reduction of existing waste bank consists of several types of waste that can be reduced, including paper, plastic, glass, iron, organic waste and other waste.

The prediction of potential waste reduction through waste bank in 10 years is presented in Table 2 assuming that the condition of waste bank will remain the same according to the existing conditions (the 1st scenario).

**Table 2. Reduction in Existing Condition (the 1st scenario).**

| Year | Reduction in waste bank (tonnes/year) | Reduction in composter (tonnes/year) | Total reduction (tonnes/year) | Waste Mass (tonnes/year) | Waste Mass at TPA* (tonnes/year) | % of reduction |
|------|-------------------------------------|-------------------------------------|-------------------------------|--------------------------|----------------------------------|---------------|
| 2018 | 0.34                                | 70.48                               | 70.82                         | 84,076.41                | 84,005.59                        | 0.08          |
| 2019 | 51.02                               | 149.99                              | 201.01                        | 84,597.68                | 84,396.67                        | 0.24          |
| 2020 | 129.94                              | 258.66                              | 388.6                         | 85,122.19                | 84,733.59                        | 0.46          |
| 2021 | 237.11                              | 396.49                              | 633.6                         | 85,649.95                | 85,016.35                        | 0.74          |
| 2022 | 372.52                              | 563.47                              | 936                           | 86,180.98                | 85,244.98                        | 1.09          |
| 2023 | 536.18                              | 759.62                              | 1,295.80                      | 86,715.30                | 85,419.50                        | 1.49          |
| 2024 | 728.09                              | 984.92                              | 1,713.01                      | 87,252.93                | 85,539.92                        | 1.96          |
| 2025 | 948.24                              | 1,239.38                            | 2,187.62                      | 87,793.90                | 85,606.28                        | 2.49          |
| 2026 | 1,196.64                            | 1,523.00                            | 2,719.64                      | 88,338.22                | 85,618.58                        | 3.08          |
| 2027 | 1,473.28                            | 1,835.78                            | 3,309.07                      | 88,885.92                | 85,576.86                        | 3.72          |

*TPA: Final Deposit Area

Simulation results of existing conditions in reducing waste in 10 years show that in 2018 the value of waste reduction that could be done was 0.08% of the total waste generation and could increase to 3.72% in 2027.

#### 3.2 Scenario based on community participation (the 2nd scenario)
In the 2nd scenario, the potential for reduction is through waste bank if the number of customers increases based on the results of the questionnaire. Reduction was planned for 10 years. The reduction in this scenario is to illustrate the amount of reduction in household waste when a waste bank and composting activity is carried out. It is known that reduction in garbage banks consists of reduction of paper waste, plastic waste, iron waste, glass waste, and other waste. Whereas in reduction with a composter, the value of waste reduction is obtained from the composting activities of organic waste. The reduction value of each type of waste is increased by the rate of increase in PF (participation factor) and RF (recovery factor).

| Year | Reduction in waste bank (tonnes/year) | Reduction in composter (tonnes/year) | Total reduction (tonnes/year) | Waste Mass (tonnes/year) | Waste Mass at TPA* (tonnes/year) | % of reduction |
|------|--------------------------------------|-------------------------------------|-------------------------------|-------------------------|---------------------------------|---------------|
| 2018 | 1.31                                 | 271.86                              | 273.17                        | 84,076.41               | 83,803.24                       | 0.32          |
| 2019 | 194.07                               | 570.55                              | 764.62                        | 84,597.68               | 83,833.06                       | 0.90          |
| 2020 | 490.39                               | 976.16                              | 1,466.55                      | 85,122.19               | 83,655.63                       | 1.72          |
| 2021 | 890.28                               | 1,488.69                            | 2,378.97                      | 85,649.95               | 83,270.98                       | 2.78          |
| 2022 | 1,393.74                             | 2,108.13                            | 3,501.87                      | 86,180.98               | 82,679.11                       | 4.06          |
| 2023 | 2,000.76                             | 2,834.49                            | 4,835.25                      | 86,715.30               | 81,880.05                       | 5.58          |
| 2024 | 2,711.35                             | 3,667.77                            | 6,379.12                      | 87,252.93               | 80,873.81                       | 7.31          |
| 2025 | 3,525.51                             | 4,607.96                            | 8,133.47                      | 87,793.90               | 79,660.43                       | 9.26          |
| 2026 | 4,443.24                             | 5,655.07                            | 10,098.31                     | 88,338.22               | 78,239.92                       | 11.43         |
| 2027 | 5,464.53                             | 6,809.09                            | 12,273.63                     | 88,885.92               | 76,612.30                       | 13.81         |

*TPA: Final Deposit Area

Simulation results based on community participation in reducing waste in 10 years show that in 2018 the value of waste reduction that could be done was 0.32% of the total waste generation and could increase to 13.81% in 2027.

4. Conclusions

The conclusions obtained from this study are:
1. The existing waste banks in South Surabaya indeed helped to reduce the amount of waste generation in 2018 by 6946.48 kg/month with the composition of the paper waste amounting to 3311.59 kg/month (48%), plastics 1777.41 kg/month (26%), glass 779.31 kg/month (11%), iron 451.21 kg/month (6%), aluminum 116.12 kg/month (2%), and other waste 510.85 kg/month (7%). These results were obtained from field observations.
2. Based on the simulation results, the 2nd scenario was the scenario with the highest number of reduction at 12,273.63 tonnes/year or 13.81% for the 10 years of period analysed. This proved that the community participation in participating in waste bank program would influence the amount of reduction that could be done through waste banks.

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