Developing e-logistics System for Plastic Recycle in Order to Enhance the Role of Community-Based Waste Bank

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Abstract

There are many established community-based waste banks in order to overcome the domestic waste, especially plastics. However, those existing waste banks did not provide sufficient economic benefits for the society. The aim of this research is to develop an integrated e-logistic system between the community-based waste banks and recycled plastics production process. This research proposes the e-logistic conceptual model for plastic waste, including raw material data in each bank, so that the data can be online monitored in real-time by each waste bank and by the manager of the recycled plastic production process. This research has the same spirit as the previous one in building an efficient logistic mechanism. Nevertheless, the proposed model is developed to not only input and record the plastic waste data as raw material, and indicate the location of the waste banks, but also incorporate a production system of the recycled plastic product and create a transportation system between the waste banks and the production facilities. The model examines an economic feasibility study by considering plastic waste supply and the added values of each stakeholder. Using the proposed model, the decision-makers can solve the plastic waste problems and reduce the environmental impacts. Furthermore, by implementing it, they may develop the recycled plastic industries and increase society's prosperity.

Keywords
E-logistic, community-based waste bank, plastic recycle, transportation system, efficient logistic.

1. Introduction

Community-based waste management called waste bank has been established for overcoming the negative impact of the wastes especially plastic waste. The community recover plastic waste from the mixed waste, collect the plastic waste and sell the plastic waste for plastic recycle product (Putri, et al, 2018). Several advantages have been expected from the waste bank activity. The main advantage is reducing the impact of hazardous waste, where plastic waste is considered as one of the most dangerous waste (Rochman et al., 2013). The plastics are made by binding small unit monomers to form long chains polymers. The polymers sometimes contain harmful ingredients or toxic materials (Rochman et al., 2013). The most toxic polymers materials are PVC, Polyurethane, and polycarbonate contribute about 30% of plastic goods production, including food packaging, furniture, electronics and automobile (Lithner et al., 2011). Most governments in the world struggle to reduce the impact of plastic waste. Several actions have been taken for that purpose. Fortunately, several communities in Indonesia have the initiative to establish the community-based waste bank. That program is expected to support government programs in managing and reducing hazardous plastic wastes. However, the benefit and of community-based waste banks is still questionable due to lack of integration, and coordination among community-based waste banks, and others stakeholder, including recycling plastic manufacturing companies and local government. Furthermore, the community did not ensure the economic benefit for their activity in running the waste bank and lead to decrease the spirit and motivation of the community nearby the waste bank. Therefore, that is necessary to build an efficient system to connect and optimize the logistic system in the community-based waste bank. Previous research proposes reverse logistics for plastic recycle (Huong, and Huong, 2019). In other research, Kristina et al., (2018) examine circular economy in the recycled plastic bottle waste supply chain. In the transportation research area, the routing and scheduling for transportation vehicles for Small Medium Enterprise is proposed (Miwa and Bell, 2017). The research utilizes location data for optimizing the route of the vehicle. Our proposed model continues the previous research for providing a logistic system for recycled plastic and considers transportation and routing problems. Different from the previous research, our research proposes not only the route but also model and simulates recycled plastic production facility. Moreover, by utilizing the model, the decision maker can determine the location of the production facility optimally. The optimum solution consider range, distance, and time required for transporting materials for all production facility and community-based waste banks.

Designing the efficient logistic model is known as the effort for increasing the industrial value added. Therefore, many previous research focused on the logistics system model. The impact of digitalization that raised the industry 4.0 influence the development of logistic and industrial supply chain model (Ivanov et al., 2018). Our proposed model has the same direction as the previous research in terms of providing efficient logistics by digitalizing the systems. However, our research develops not only the plastic waste as raw material data on the digital system, but also incorporates recycled plastic production system, optimize the transportation system of raw material and product, optimize the profit of all stakeholders as decision maker, and also feasibility study of the built system.

In our research, each manager of community-based waste banks, and manager of the recycled plastic production facility are the decision makers. To date, however, no reports in the literature have proposed a model e-logistic that incorporates different objectives for the stakeholders. We intend to optimize the model and satisfy all decision makers by using a mathematical model with multi objectives. The proposed model involves community who are weak in areas such as capital generation, technology and finance (Gunasekaran et al., 2011). Therefore, this research utilizes the profit sharing mechanism between the decision makers. Profit sharing is known as the mechanism of reducing risk by sharing the risk and profit. Previously, a profit sharing scheme has been applied in two firms joint venture in technology (Du et al.,2006; Jiang et al, 2010), SME finance (Takalo and Tanayama, 2010) and university technology incubator (seno wulung, 2018).

This paper has contributions: First, we propose a model that minimizes the impact of plastic waste by optimizing the production of recycled plastic products. Second, we determine the location of recycled plastic production facilities that provide optimum conditions in the recycled plastic supply chain. The model considers the amount of raw material, range, distance, and time for moving the plastic waste from the community-based waste bank to production facilities. Third, we use a profit sharing scheme to accommodate the different objectives of the stakeholders. We utilize the multi-objective to reach an optimum solution and satisfy the decision makers.

1.1 Objectives

Focusing on the community-based waste bank, particularly on managing the plastic waste, the research has objectives as follow:

1. Develop an e-logistic system for plastic waste material in the community-based waste banks for monitoring raw material, production activity, and distribution.
2. Model the e-logistic system for incorporating the stakeholders consist of the community-based waste banks and recycled plastic production facility.
3. Optimize the model and provide the solution that satisfies the stakeholders.

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2. Literature Review

Plastic is known as an engineering material that used in many kind of products, such as electronics, automotive, and ware house including bottles. That's situation has a significant impact on the environment, due to the difficulty to break down the material in the soil. In order to reduce the impact of plastic waste, many communities established waste banks (Kristina et al, 2018). The local government takes advantage of the establishment of the community-based waste banks (Sahwan et al., 2005). Unfortunately, the local government doesn't have a sufficient separation process for separating plastic waste from mixed waste (Damanhuri and Padmi, 2016). Therefore, the local government depend on the informal separation in community-based waste banks (Damanhuri and Padmi, 2012). The community-based waste banks separate and categorize the waste, and sell the separated plastic waste to the collectors and then to the recycled plastic manufacturing plant. That situation has economic advantages, since the plastic material can be recycled six time. That means the community-based waste banks is included in the recycled plastic supply chain

(Huong and Huong, 2018). Therefore, the community-based waste banks have economic potential that promising to be developed.

Previous research proposed reverse logistic to optimize the role of the community-based waste banks (Daugherty et al, 2005). The research conducted data tabulation in the level meso-industy, identify the stakeholder in the recycled plastic industry, and try to arrange the logistics in reverse flow. Unfortunately, the previous research didn't provide discussion about collector supply mechanism, production unit and the market, and didn't consider the added value for each stakeholder in the supply chain.

Kristina et al. (2018) conducted research for increasing the amount of recyclable plastic waste. The research proposed the recycling process for increasing the number of plastic types that can be recycled. That purpose based on the fact that only limited plastic available to be recycled. Based on the data, only 30% of plastic waste was recycled, 39% incinerated, and the rest 31% sent to the landfill (EU Commission, 2020). However, Kristina et al. (2018) only focused on the recycling process, and not consider the distribution line, the need for raw material mapping, and the profit for each stakeholder in the supply chain.

Logistics is the activity that copes the product movement and the information between the stakeholders in the supply chain (Bowersox et al., 2002). In the industry 4.0 era, the use of information and communication technology (ICT) has an important role in the efficient coordination and integration along the supply chain (Tongzon and Nguyen, 2013). Tongzon and Nguyen (2013) assessed the use of ICT in the logistic company in ASEAN countries. The result shows that Singapore's companies have the highest level for adopting ICT and the companies from Cambodia is the lowest. Furthermore, the research indicated that the low ICT adoption for the logistic system in ASEAN leads to the insufficient impact of the logistic companies to the economic performance. Unfortunately, the research didn't conduct a thorough assessment along the supply chain. Moreover, the research didn't provide a more sophisticated system for enhancing the use of ICT in the companies.

Providing an efficient logistic system is very important to reduce the company's cost. The vehicle routing and scheduling algorithm is the determinant for creating efficient logistics (Laporte, 1992). Therefore, the previous research raised issues about vehicle routing and scheduling. For solving the difficulties in mathematical model and optimization, some computer software are developed. Despite the importance, the software are too expensive for small and informal enterprises such as the community-based waste banks. Therefore, Miwa and Bell (2017) proposed efficient routing and scheduling for small enterprises based on the location data of the vehicle. In that research, each vehicle is equipped with a smartphone which the driver can access the demand of services and determine the best route. The research was conducted based on the previous research by Gunasekaran (2007). Gunasekaran (2007) stated that real time information will beneficial to enhance the performance of small enterprise logistics. However, the research didn't calculate the range and distance between the small enterprises, the buyers and others actors in the supply chain. The research also didn't consider the capacity of materials transported, and the economic value for the small enterprise.

Our research in line with Kristina et al., (2018) in terms increases the usability of plastic waste and the amount of recycled plastic. However, because the focus of the research is the regional waste banks community, this research considers the location for establishing the recycled plastic production facility, the range and distance of both the production facility and the community-based waste banks that spread around the city. This research has the same spirit as Huong and Huong (2018), and enhances the research by adding the amount of the materials supply and the added value of the stakeholders in the supply chain. This paper utilizes profit sharing, that similar to previous research. Du et al., (2006) use the profit sharing scheme for two firm joint venture while Seno Wulung et al., (2018) implement the scheme in technology incubator. For increasing the performance of the system, this research proposes software that incorporates the amount of separated plastic waste from each waste bank community, the production capacity of recycled plastic, materials distribution path, and the profit for each stakeholder.

3. Model Development

The model development consists of:

3.1. The community-based waste bank mapping

The first step, in the model development is identifying and mapping the community-based waste banks. Based on the data, we determine the waste banks zone, calculate the range of the waste banks, the distance between the waste banks, and determine the location of the recycled plastic production facility. The factors that influence this step are the capacity of each waste banks, and routing and scheduling of material transportation. The model is shown in Figure.1.

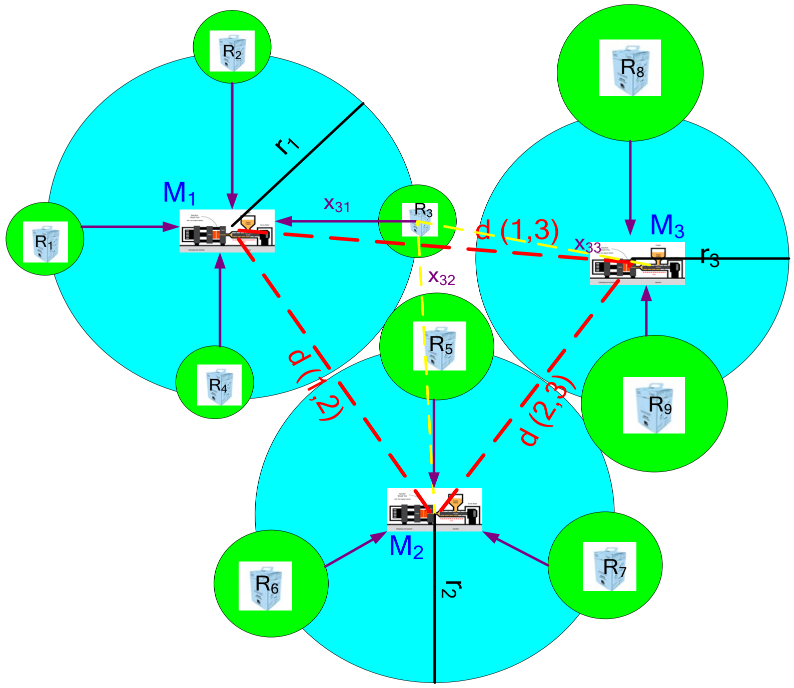

Figure 1. The waste bank mapping and determining the location of production

Based on Figure 2, the range and capacity of each production facility are not uniform, depend on the distance and the amount of the waste banks supply. In the figure 2, production unit M_1 has range $2r_1$, M_2 has range $2r_2$, and M_3 has range $2r_3$ and then M_i has range $2r_i$. The distance between each production unit notated as d(1,2) for the distance between production unit 1 and production unit 2, d(1,3) for production unit 1 and 3, while d(2,3) is notation for the distance between production unit 2 and 3. Furthermore, waste bank R_1, R_2, R_3, …R_j will send the separated plastic waste as raw material to the nearest production unit. For example; waste bank R_3 will send the plastic waste to M_1 with distance x_{31}, compare to sending the materials to M_2 that has distance x_{32} or M_3 with x_{33}, when x_{31} has shortest distance compare to x_{32} or x_{33}. Similarly, the calculation is conducted for all production unit and the community-based waste banks.

3.2. Determining the role and profit for all stakeholders

We consider the situation that involved three stakeholders, they are the production facility manager, the community-based waste banks manager, and the transportation company. The income for the community-based waste bank is decided after the profit of the recycled plastic has been generated by utilizing the profit sharing scheme. Firstly, the net profit of the production facility is determined based on the eq.1 as follow:

$$Ve_i = \sum_{j=1}^{k} (1 - S_{ij}) \Pr_{ij} \qquad \text{..................(1)}$$

While $\Pr_{ij}$ is the gross profit of the recycled plastic product in production facility (i) based on raw material from the waste bank (j). After the product is sold, the production facility manager will share the profit S_{ij} to the waste bank (j) based on the quality of the raw material. The quality material is determined based on the conversion rate, α. The percantage of profit share in the range 0 -1 and negotiable between the production facility manager and the community-based waste bank. Then, the gross profit $\Pr_{ij}$ of the production facility can be determined as follow:

$$\Pr_{ij} = \left(r_{ij} - Cp_{ij}\right)Q_{ij}\,\alpha_{ij} - Ct_{ij} \qquad \text{......................(2)}$$

Where Ct_{ij} is transportation cost for transporting the material from the waste bank (j) to the production facility (i). the cost is paid to the tarsnportation company.

Then, the profit of each community-based waste bank is state as follow:

$$Vv_j = \sum_{i=1}^{l} S_{ij} \Pr_{ij} \qquad \text{......................(3)}$$

The profit of the transportation company is based on the payment by the production facility. The profit is:

$$Vt = \sum_{i=1}^{k}\sum_{j=1}^{l} Ct_{ij} \qquad \text{......................(4)}$$

The consequence of the equation (4), the transportation company should optimize the route and schedule of their vehicles dynamically by monitoring the application that will be built. The factors are the amount of material, the distance, and the number of waste bank that served by each vehicle.

3.3. E-logistics Application Development

Our research intends to design and build the e-logistics application for managing recycled plastic based on the model in section 3.1. and mathematical model in section 3.2. The function of the e-logistic application is as an aggregator of the community-based waste banks. The information about the plastic waste and the recycled plastic product will be inputted, and monitored by the decision makers. The information consists of the amount of plastic waste, the number of recycled products, the conversion rate of the plastic waste, the profit of the recycled plastic product, and profit sharing for the community-based waste banks. The role of the e-logistics aggregator as follows:

a. For the community-based waste banks
   1. Collect and input the plastic waste as raw materials
   2. Monitor the raw materials that sent to the production unit
   3. Monitor the yield of production
   4. Get the information about the profit sharing
b. For the production unit
   1. Get the information about the amount of the supply raw materials
   2. Find the customer demand for arranging the production schedule.
   3. Inform the product price
   4. Inform the production cost including the transportation cost that paid to the transportation company
   5. Inform the sales, profit, and profit sharing for the community-based waste banks partner.
c. For the customer
   1. Obtain the price information
   2. Make the order of product

The use of the e-logistic application by the stakeholders is described in the Figure 2.

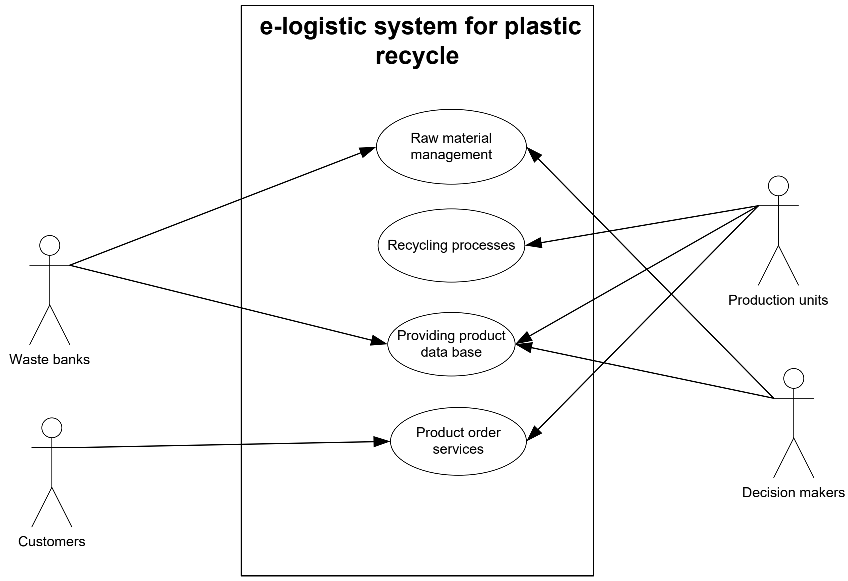

Figure 2. The use of the e-logistic application for stakeholders

For realizing the e-logistic application, we develop application for waste banks, production units and the consumers. The developing process of the application for the community-based waste bank is shown in figure 3.

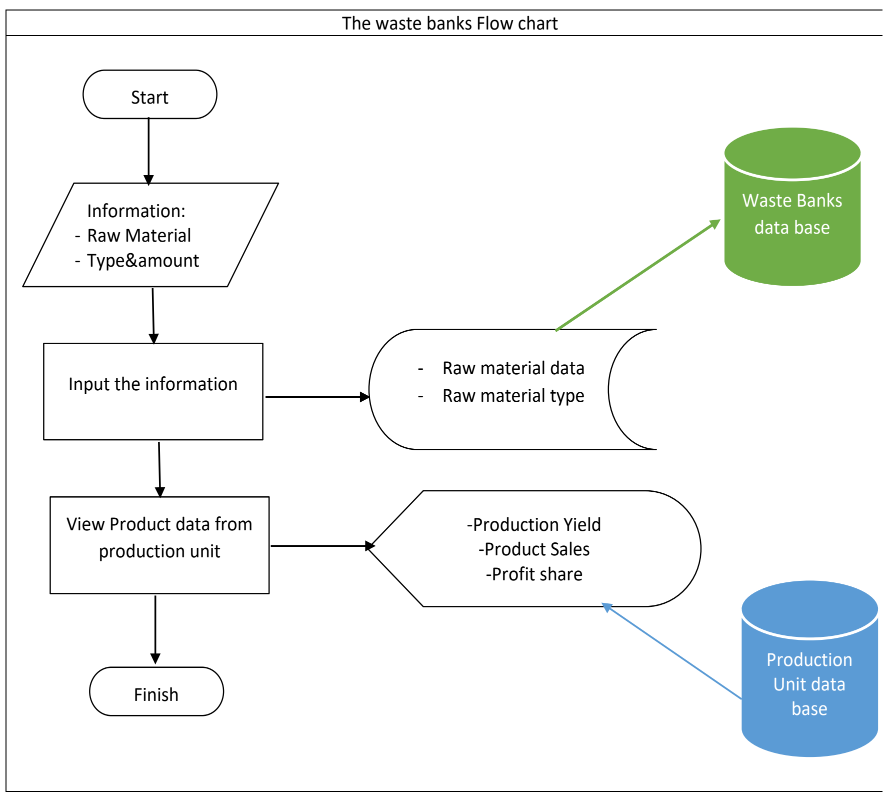

Figure 3. Application design flow chart for the community-based waste banks

Our research also proposes the application for the production unit and for the consumers, the flow chart for the production unit is depicted in the figure 4, while the flow chart for the customer is shown in figure 5.

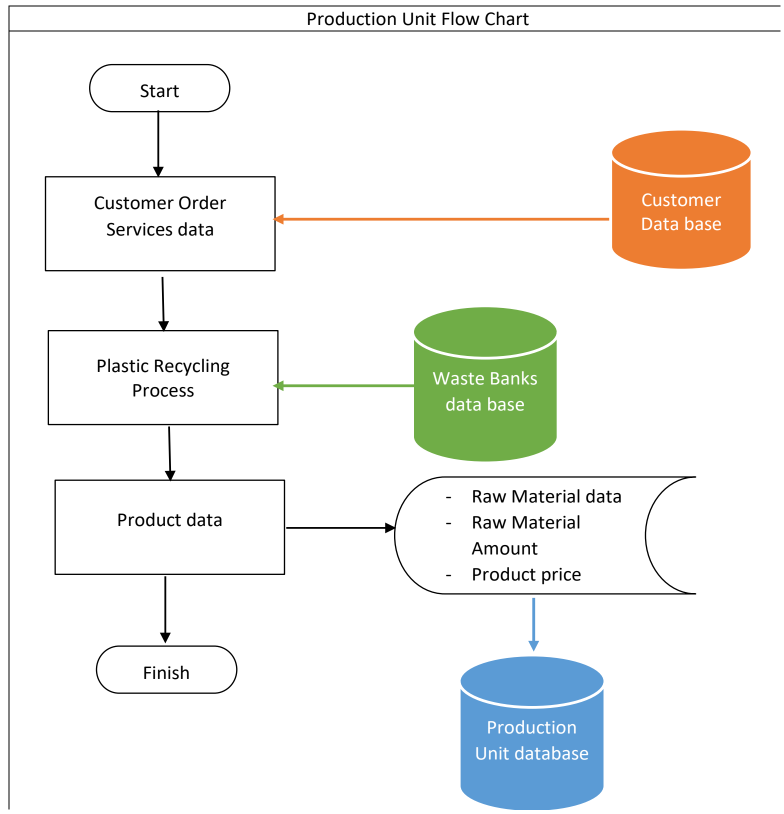

Figure 4. Application design flow chart for the production unit

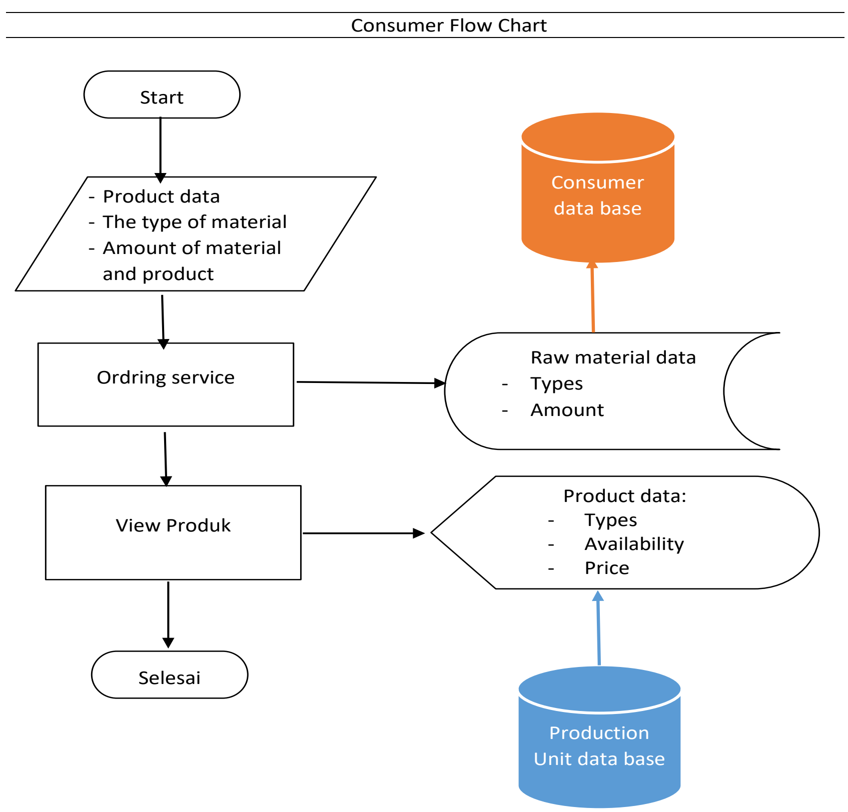

Figure 5. Application design flow chart for the consumer

The design as shown in figure 3 to figure 5 facilitates the community-based waste banks, the recycled plastic production unit, and the consumer. The transportation company that provides vehicles to transport the raw material plastic waste can assess both the application for waste banks and the production unit. The situation is to facilitate the transportation company for optimizing their route and schedule.

4. Data Collection

The data will be collected for five districts in special region of Yogyakarta. However, the mapping will be conducted for each city. For example; there are exist about 200 community-based waste banks in Sleman, then the model for Sleman district will be separated with other districts.

5. Expected Results and Discussion

In this section, we will describe the expected result of our proposed model for community-based waste banks, production unit, and the transportation company. The expected result can be tabulated as shown in table 1.

Table 1. The tabulated result for the community-based waste banks

Waste Banks	Periode 1				Periode 2				....	Periode- n			
	Amount	%Converted	%profit Sharing	Profit (Rp.1000)	Amount	%Converted	%profit Sharing	Profit (Rp.1000)		Amount	%Converted	%profit Sharing	Profit (Rp.1000)
R_1	300	60%	30%	10000	500	40%	15%	7000		400	80%	40%	15000
R_2													
R_3													
R_4													
.....													
.....													
.....													
R_j													

The tabulated result of the production facility for each period is described in Table 2.

Table 2. The tabulated result of the production facility in each period

Production Facility	Waste Banks R_1				Waste Banks R_2				....	Waste Banks R_j			
	Amount	%Converted	%profit Sharing	Profit (Rp.1000)	Amount	%Converted	%profit Sharing	Profit (Rp.1000)		Amount	%Converted	%profit Sharing	Profit (Rp.1000)
M_1	300	60%	70%	27000									
M_2													
M_3													
......													
.....													
.....													
M_i													

Based on table 1, the community-based waste banks can monitor the amount of plastic waste that send to the production facility for each period. Moreover, the community-based waste banks can identify how much received profit sharing can be obtained based on the percentage of plastic waste conversion to the recycled plastic product. The amount of profit for each waste bank depends on the amount of plastic waste and the conversion percentage. In table 2, the production facility manager can review the quality of the supplied plastic waste from the waste banks based on the conversion percentage. The higher quality plastic waste is indicated by higher conversion to the recycled plastic product. Furthermore, by utilizing the result, the production facility manager determines the amount of profit that should be shared to the community-based waste bank based on the supplied material quality. The rationale is the higher quality of the plastic waste lead to an efficient production process and reduces the production cost as higher of the recycled plastic product yielded.

Then, we also provide the expected result of our proposed system for the transportation company depicted in table 3.

Table 3. The vehicle assignment

Vehicle	Periode 1				Periode 2				....	Periode- n			
	Plastik Waste Amount	Number Of R	Distance (Km)	Cost (Rp.1000)	Amount	Number Of R	Distance (Km)	Cost (Rp.1000)		Amount	%Converted	%profit Sharing	Profit (Rp.1000)
V_1	400	29	350	320									
V_2					350	35	375	360					
V_3										350	35	375	360
V_4													
…..													
…..													
…..													
V_k													

Regard to table 3, the transportation company can review the operational cost of their vehicle that transport the material from the community-based waste banks to the production facility. The table indicated that the cost is influenced by the number of the waste banks node, distance, and amount of the plastic waste. That situation make the transportation can review select the best route and schedule of their vehicle.

6. Conclusion and Future Work

In this paper, we proposed the recycled plastic e-logistic model for enhancing the role of the community-based waste banks. In our model, we provide a system that incorporates the stakeholders, consist of the community-based waste banks, the production facility and the transportation company. The community-based waste banks send the plastic waste to the production facility by utilizing vehicle that provided by the transportation company. Furthermore, we utilise a profit sharing scheme in our proposed model due to the uncertainty of the plastic waste quality and volume. The quality of the plastic waste is related to the conversion rate for producing the recycled plastic product. The rate is defined as how much the waste can be converted to the product and stated in the percentage. The higher conversion rate leads to an efficient production process in the production facility. Therefore, the production facility manager shares higher profits to the community-based waste bank. Different from the production facility and the community-based waste banks, the transportation company will be paid by the production facility based on the amount of supplied materials. Because many community-based waste banks are spread in the area, the challenge of the company is to arrange the most efficient route and schedule for their vehicles. Our proposed model derived several managerial implications for the decision makers. First, the community-based waste banks tend to conduct the waste separation process better, regarding to the quality and their profit sharing. Second, by using our model, the production facility manager can ensure the quality of the raw materials. Third, the utilization of the mapping in our model can be used by the transportation company for optimizing their route and schedule.

6.1.Future work

Our model should be proved by a numerical experiment using the data from regional community-based waste banks. Moreover, we need to conduct feasibility studies before implementing our proposed model.

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Biography

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