Model Reverse Logistics System of Plastic Waste Recycling at Indonesia

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Abstract. The development of plastic waste recycling model in reverse logistics network system is based on plastic waste management business activities in Indonesia, which is also reinforced by some literature on similar business activities in several other countries such as India (Hess, et al., 2001; Reddy, et al., 2003) and Turkey (Nesser, et al., 2008). The reverse logistics system in Indonesia is one of the best alternatives that can be considered to reduce the limitations of raw material resources. In addition, reverse logistics proved to provide economic value to business actors (Rivera and Ertel, 2008), then environmental issues became one of the strongest motivations for reverse logistics (Francas and Minner, 2009; Schultzmann, et al., 2006). The objective of the research is to develop plastic waste recycling model, especially LDPE (Low Density Polyethylene) and HDPE (High Density Polyethylene) plastic in the reverse logistics network system and determine the distribution and transportation network related to the plastic waste management business activity. Models can be developed based on empirical data with several scenarios in observing the behavior and characteristics of model variables. Model results can be generated minimize the total cost of reverse logistic system in plastic waste management in Indonesia IDR 196,220,250.

1. Introduction

The concept of green supply chain focuses on the possibility of implementing reverse logistics, which is including conventional logistics. Implementation of Green Supply Chain has a rule called Dismantlers, which in Green logistics concept functions to operate additional functions in recovery and recycling. Uncertainty is inherent in the implementation of reverse logistics that challenge the concept of Green Supply Chain. Conventional supply chain, uncertain demand is only influenced by inventory levels, production quantities, and logistics.

Uncertainty factors in reverse supply chain is very complex compared to the forward supply chain. The uncertain portion of demand on reverse logistics is the value of recovery and land filling values that are difficult to estimate, both of which greatly contribute to reverse logistics management (Kongar, 2004; Ovidiu, 2007; Salema et al., 2007). Reverse logistics is currently the best alternative that can be considered to reduce the limitations of raw material resources. In addition, reverse logistics proved to
provide economic value to business actors (Rivera and Ertel, 2008), then environmental issues became the strongest motivation for reverse logistics (Francas and Minner, 2009; Schultzmann, et al., 2006).

2. Literature Review
Studies reverse logistics can be divided into several categories. Dowlatshahi (2000), have identified into five (5) categories including: global concepts of reverse logistics, quantitative models, logistics (distribution, warehousing, and transportation), company profiles, and applications. More recently, some researchers have been concentrating on the optimization and quantitative models in reverse logistics. Most of the proposed model is the traditional model of facility location models, and mixed integer linear models (Kroon and Vrijens, 1995; Ammons et al., 1997; Spengler et al., 1997; Barros et al., 1998; Marin and Pelegrin, 1998; Jayaraman et al., 1999; Krikke et al., 1999; Fleischmann et al., 2001). Other researchers studying the problems with the single exception of inbound commodity Spengler et al. (1997) and Jayaraman et al. (1999).

The main activity of reverse logistics is to collect the product to be renewed, and redistribution of new material generated (de Britto, et al, 2002). Furthermore, de Britto, et al (2002) divides the logistics to reverse logistics network into four parts. This distinction is made by the initiator of the activity of reverse logistics. The logistics network includes: logistics network for reusable products, logistics network for remanufacturing, logistics network for community services and environmental regulation by the government and by private logistics network for product renewal. Challenges in the reverse logistics of course the application of reverse logistics which has its own challenges in its implementation. Unlike the case with forward logistics, reverse logistics in there are some challenges as follows:

1. Forecasting the return product becomes more difficult because there are no data regarding the exact distribution EOL product for speed product returns are difficult to measure.
2. Transportation is quite difficult because it must collect from many places before it is turned back into the supply chain (many to one transportation), so that in determining the route of products returned will be complex.
3. Determination of the quality of product returns are influenced by many factors such as the condition when the product is returned, who is using and how the product is used.

3. Methodology
3.1. Framework
The condition of the plastic waste reverse logistics system occurring in the recycling industry is a framework in this research. Integrated supply chain system in the management of plastic waste can provide optimal benefits for the stakeholders economically, socially, and environmentally. Case study on plastic waste management supply chain system in plastic waste recycling industry, due to the absence of integrated system in waste management, the researcher develops model entities related to supply chain management of plastic waste management and identifies plastic waste capacity, costs on each entity, as well as multi actors in the supply chain. Engineering model that formed can be made a planning decision model of plastic waste management and planning pattern of plastic waste collection from collection centers and planning of distribution of recycled result to distributors, so that from result of proposed model which is expected to give description of plastic waste for stakeholder.

3.2. Approach
This research is expected to develop engineering reverse logistic system decision model in plastic waste management case study in recycling industry in Indonesia. Reverse logistic system of plastic waste management involves many integrated stakeholders who interact with each other in achieving certain goals. To achieve an integrated reverse logistic system requires several approaches, namely the conceptual approach and the mathematical approach. Conceptual approach in this research is needed is a system approach (system of thinking) that can describe the interrelations of elements in the system as an integrated entity. In addition to the system approach is also required concepts that are integrated, such as the concept of Design for Environment (DFE), the concept of Green Supply Chain Management, the
The concept of Reverse Logistic, and the concept of System Design. Based on the simplification of the issues discussed and to facilitate understanding, the engineering of plastic waste management will be developed mathematical model.

4. Model Results

The data collection model parameters developed can be identified based on the structure, flow, and process in the reverse logistics system of plastic waste management. Reverse logistics network system in the flow and process of plastic waste that occurs in the final consumer (k = 1), scavenger (k = 2), garbage bank (k = 3), collector (k = 4), agent (k = 5) Recycling plant (k = 6), and Consumer economical product (k = 7) are illustrated in Figure 1 below.

![Figure 1. Flow and Process of Reverse Logistic of Plastic Waste on Each Entity.](image)

In the flow and process reverse logistics system discusses the various kinds of data obtained by the author, both primary data collection and secondary data collection. Primary data collection is done by conducting interviews and interviews directly in the field to every actor or entity involved in the reverse logistic system of plastic waste recycling, while the secondary data collection is done by obtaining direct information from the company, especially in the entity of waste processing recycling plant plastic into an economical product, in this case PT Trilion Multiplasindo company that produces plastic waste plastic materials Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) which produce economical products with the product name "Tutup Galon JKT". Based on the estimation and identification of some parameters model, it can be illustrated in table 1 of recapitulation data of parameter estimation of reverse logistic model.

| Model Parameters | Entity/Stage | Unit |
|------------------|--------------|------|
| Wk               | k = 1        | Kg   |
|                  | k = 2        | Kg   |
|                  | k = 3        | Kg   |
|                  | k = 4        | Kg   |
|                  | k = 5        | Kg   |
|                  | k = 6        | Kg   |
|                  | k = 7        | Kg   |
| Ck               | 10,000.00    | Kg   |
|                  | 15,000.00    | Kg   |
|                  | 9,000.00     | Kg   |
|                  | 13,500.00    | Kg   |
|                  | 10,000.00    | Kg   |
|                  | 14,000.00    | Kg   |
|                  | 14,400.00    | Kg   |
| sk               | 0.10         | %    |
|                  | 0.10         | %    |
|                  | 0.20         | %    |
|                  | 0.20         | %    |
| Csk              | 500.00       | Rp/Kg|
|                  | 600.00       | Rp/Kg|
|                  | 850.00       | Rp/Kg|
|                  | 1,000.00     | Rp/Kg|
| CDk              | 500.00       | Rp/Kg|
|                  | 800.00       | Rp/Kg|
|                  | 1,600.00     | Rp/Kg|
|                  | 1,200.00     | Rp/Kg|
| CPk              | 7,500.00     | Rp/Kg|
| Fk               | 0.40         | %    |
|                  | 0.40         | %    |
|                  | 1.00         | %    |
|                  | 1.00         | %    |
| TQTk             | 2,000.00     | Kg   |
|                  | 2,000.00     | Kg   |
|                  | 2,000.00     | Kg   |
|                  | 2,000.00     | Kg   |
| QTK              | 2,000.00     | Kg   |
|                  | 100.00       | %    |
|                  | 100.00       | %    |
|                  | 2,000.00     | %    |
|                  | 2,000.00     | %    |
| Fk               | 11           | Times|
|                  | 9            | Times|

![Figure 2. Reverse Logistics Model Parameters](image)

From the reverse logistics model parameters data, total data of garbage truck transport capacity (TQTk) in each entity garbage bank (TQT1), Collector (TQT2), Agent (TQT3), and TQT6 plastic recycling factory (TQT6) is equal to @ 2,000 Kg, with the percentage of transport capacity in each entity.
is different, because that is transported by truck not only plastic waste (LDPE and HDPE), but there are other types of garbage. For Garbage Bank, the percentage of plastic waste transported (f3) is 40% of the LDPE and HDPE plastic waste, then the percentage of plastic waste transported to the Collector entity (f4) is 40%, but for the percentage of plastic waste in the Agent entity is 100% to be distributed to recycling Plant entities. Similarly, for recycling plant entities, since plastic waste has been processed into economic products, then the percentage of economic products that will be distributed to the end consumer of economic products (f6) is 100% economic product. Based on the above data, it can be measured the distance of plastic waste transport between entities, which can be illustrated with table 2, below.

![Figure 3. Distance of Plastic Waste Transportation](image)

In addition to the distance of plastic waste transport, also identified transportation costs between entities in the reverse logistics model. Transportation costs between entities can be estimated in the mode of transport during full load conditions and empty mode of transport conditions. For transportation cost data (CTk) when the condition of full load mode transport can be seen in table 3, below.

![Figure 4. Transportation Costs (CTk) Condition](image)

Transportation cost data (CTk) at the time of empty mode of transport can be seen in table 4, below.
The objective function of this research model is to minimize the total cost of reverse logistic system of plastic waste recycling. Based on the explanation that at each entity can be identified 4 (four) cost components in the reverse logistic system of plastic waste recycling, as follows: Minimum $TC = TCT + TCS + TCD + TCP$.

**Transportation Cost (CT_k)**

Total Cost of Transportation (TCT) that occurs in the reverse logistic system of plastic waste recycling management in Indonesia, especially HDPE and LDPE plastic waste that can be formulated below.

$$TCT = TCT_5 + TCT_56 + TCT_67$$

$$TCT = W_k \cdot d_{54} \cdot CT_{54} + W_k \cdot d_{45} \cdot CT_{45} + W_k \cdot d_{53} \cdot CT_{53} + W_k \cdot d_{35} \cdot CT_{35} + W_k \cdot d_{56} \cdot CT_{56} + W_k \cdot d_{65} \cdot CT_{65} + W_k \cdot d_{67} \cdot CT_{67} + W_k \cdot d_{76} \cdot CT_{76}$$

$$TCT = IDR \ 37,334,250, - / \text{month}.$$  

Notation:
- $W_k$ : Demand of plastic waste in entity k (Kg).
- $v_k$ : Percentage of waste disposal is not relevant (%).
- $CT_k$ : Cost of transporting plastic waste from entity k to k+1 (IDR/Kg/Km).
- $TCT$ : Total cost of transporting plastic waste from entity k to entity k + 1 (IDR).

**Sorting Cost (CS_k)**

Costs derived from sorting activities, separation, and cleaning of plastic waste raw materials prior to processing. This activity aims to separate waste that can be processed plastic (relevant and feasible) and that can’t be processed. Relevant plastic waste will be used as the base of plastic waste raw materials in the recycling process, whereas the irrelevant plastic waste ($v_k$) is the disposal/contaminant that the disposal process must do. Sorting Cost = Sorting Cost/Kg of plastic waste in entity k (CSk) multiplied by plastic waste demand to entity k ($W_k$). The proposed model suggests that plastic waste sorting activities occur only in Bank Waste entities (k=3), Collectors (k=4), Agents (k=5), and Recycling plants (k=6). So the total cost of plastic waste sorting as follows:
TCS = CS₁ . (1-\(v_3\)) . \(W_1\) + CS₄ . (1-\(v_4\)) . \(W_2\) + CS₅ . (1-\(v_5\)) . (\(W_3 + W_4\)) + CS₆ . (1-\(v_6\)) . \(W_5\)
TCS = IDR 42,300,000,-/month

Notation:
CSₖ : Cost of plastic waste sorting entity k (IDR/Kg).
TCS : Total Cost of Sorting entity k (IDR).

Disposal Cost (CDₖ)
Costs incurred by a number of inappropriate and irrelevant plastic waste are used as plastic waste processing materials in a reverse logistic recycling system. Disposal costs = The disposal/plastic waste dump of the entity k (CDₖ) is multiplied by the percentage of inappropriate and irrelevant plastic waste in the k (vk) entity multiplied by the plastic waste demand of the entity k (Wk). Based on sorting activities, there will be disposal due to inappropriate plastic waste and also irrelevant. Disposal activities occur in entities: Garbage Bank (k = 3), Collector (k=4), Agent (k=5), and Plastic waste recycling plant (k=6). So the total cost of plastic waste disposal is as follows:

\[ TCD = CD_3 . v_3 . W_3 + CD_4 . v_4 . W_4 + CD_5 . v_5 . W_5 + CD_6 . v_6 . W_6 \]

TCD = IDR 8,586,000,-/month

Notation:
CDₖ : Cost of disposal of waste in entity k (IDR/Kg).
TCD : Cost of disposal of waste in entity k (IDR/Kg).

Processing/Production Cost (CPₖ)
Cost of the reverse logistic system process of recycling plastic waste and producing economical products. Processing cost consists of the main component, namely the cost of processing plastic raw materials (CPₖ). Processing Cost = Cost of processing plastic waste raw materials in entity k (CPₖ) is multiplied by the demand of plastic waste produced and delivered to the next entity (Wk). Processing costs are only available to reverse logistic factor y entities in recycling plastic waste (k=6). At entity Factory Recycling (k=6), the plastic waste results segregation in the entity processing and processed into finished products processed/economical “Tutup Galon JKT” for distribution to the final consumer/processed products system of reverse logistics recycling of plastic waste, which consists of components processing costs of plastic waste raw materials (CP₆). So the total cost of plastic waste processing is as follows:

\[ TCP = CP_6 . W_6 \]
TCP = IDR 108,000,000,-/month

Notation:
CPₖ : Production cost of plastic waste entity k (IDR/Kg).
TCP : Total cost of plastic waste processing (IDR).

The mathematical model of objective function of reverse logistic system based on transportation cost, sorting cost, disposal cost, and processing cost are as follows:
Minimum TC = (TCT) + (TCS) + (TCD) + (TCP)
Minimum TC = (\(\frac{W_4}{TQT_4 . f_4}\) . \(d_{54} . CT_{54}\) + \(W_4 . d_{45} . CT_{45}\)) + (\(\frac{W_3}{TQT_3 . f_3}\) . \(d_{53} . CT_{53}\) + \(W_3 . d_{35} . CT_{35}\)) + (\(\frac{W_5}{TQT_5 . f_5}\) . \(d_{56} . CT_{56}\) + \(W_5 . d_{65} . CT_{65}\)) + (\(\frac{W_7}{TQT_7 . f_7}\) . \(d_{76} . CT_{76}\) + \(W_7 . d_{76} . CT_{76}\)) + (CS₁ . (1-\(v_3\)) . \(W_1\) + CS₄ . (1-\(v_4\)) . \(W_2\) + CS₅ . (1-\(v_5\)) . (\(W_3 + W_4\)) + CS₆ . (1-\(v_6\)) . \(W_5\) + (CD₃ . \(v_3 . W_3\) + CD₄ . \(v_4 . W_4\) + CD₅ . \(v_5 . W_5\) + CD₆ . \(v_6 . W_6\) + (CP₆ . \(W_6\))}
Minimum TC = IDR 196,220,250,-

5. Conclusions
Optimization of plastic waste recycling model in reverse logistic network system in Indonesia resulted in a mathematical model of linear programming with objective function to minimize total cost of recycling reverse logistic system based on decision variables, including: number and capacity of plastic waste, location and transportation route. The cost components of the reverse logistic recycling system are: transportation costs (CTk), sorting costs (CSk), disposal costs (CDk), and processing/production costs (CPk). The solution of the reverse logistic system model model of recycling of plastic waste is shown by the total minimum system cost of IDR 196,220,250,- which is implemented on the condition of the existing system.

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References

[1] Bowersox, Donald J., David J. Closs, & M. Bixby Cooper. (2003). Supply Chain Logistics Management, New York :McGraw-Hill.
[2] Chopra, Sunil and Peter Meindl (2001).Supply Chain Management, Strategy, Planning, and Operation, Fourth Edition, Prentice Hall.
[3] Cooper, M.C., Lambert, D.M. and Pagh, J.D. (1997) Supply chain management: more than a new name for logistics, International Journal of Logistics Management, Vol. 8, No. 1, 1-13.
[4] Corbett C. and Kleindrofer P.R. 2001a. Introduction to the Special Issue to the Environmental Management and Operation (Part 1: Manufacturing and Eco-logistics). Production and Operations Management, 10 (2).
[5] Dowlatshahi S. 2000. Developing a Theory of Reverse Logistics. Interfaces, 30(3): 143-155.
[6] Fleischmann M., Bloemhof-Ruwaard J. M., Dekker R., Van der Laan E., Van NunenJ.A.E.E.,andWassenhove L.V. 1997. Quantitative Models for Reverse Logistics: A Review. European Journal of Operational Research, 103: 1-17.
[7] Gemma Berenguer-Falguera, 2012. A New Approach in Supply Chain Design:studies in reverse logistics andnonprofit settings, A dissertation, University of California, Berkeley.
[8] Ghiani, Gianpaolo, Gilbert Laporte, & Roberto Musmanno. (2004). Introduction to Logistic Systems Planning and Control. West Sussex, England: John Wiley & Sons Ltd.
[9] Hamid Pourmohammadi, MagedDessouky*, and Mansour Rahimi, A Reverse Logistics Model for Distributing Wastes/By-products,University of Southern California, 1990.
[10] Kostecki M. 1998. The Durable Use of Consumer Products: New Options for Business and Consumption, Kluwer Academic Publishers.