Reverse logistic location problem for electrical and electronics equipment waste treatment facility

E Fatma [1*]
[1] Department of Logistics Management of Electronic Industry, Politeknik APP Jakarta

* rika-fatma@kemenperin.go.id

Abstract. Reverse logistics plays a significant role in reducing electrical and electronics equipment waste (e-waste) problem by returning some valuable or hazardous parts back to the distributor or producers. This paper implemented reverse logistics facility's location problem to find the optimum location of e-waste treatment facilities. E-waste treatment facility location was determined in two phase. First, facility location model is developed to find the optimum location for e-waste treatment facility from the e-waste collecting points using K-means clustering and centre of gravity algorithm. Once the treatment facility location is decided, e-waste collection vehicle routing model is developed using saving matrix algorithm to minimize collecting distance. This paper was developed in three scenarios, based on e-waste collection problem in Jakarta. It is found that multi e-waste treatment facilities, gave the shortest collection distance compared to single and restricted area facility scenarios.

1. Introduction

The rapid growth in the electronics industry and the shortened lifespan of electronic products have led electrical and electronics waste (e-waste) as a major environmental issue. Honda, Khetriwal & Kuehr (1) reported that the e-waste resulted globally already reached 48.1 million tons between 2010-2015. Unfortunately, only a small amount of e-waste is managed properly or entered into the proper waste management system. Based on the data, Indonesia produced 812 kilotons of e-waste in 2015. It means approximately each person in Indonesia produced 3.25 kg of e-waste in 2015. E-waste is generated by electronics products that have been discharged or damaged. In this era, where electronics product life cycle is getting shorter, E –waste management is highly needed since various elements in e-waste can be classified as hazardous to the environment. On the other hand, e-waste still has a high economic value since it contained precious metal and other precious elements.

In fact, the Indonesian government has obliged companies to take the responsibility for their waste management system, especially for the non-biodegradable waste. Unfortunately, this regulation is not yet regulates specifically on e-waste treatment and management. Whereas, some developed countries already have a regulation that obliged companies to perform the extended producer responsibility (EPR). This regulation is a form of company's responsibility for the environmental impact caused by their products which no longer used, it is also obliged companies to manage their e-waste. However, regulation concerning EPR has not been adopted by electronics companies in Indonesia. Most of the companies considered that the development of e-waste management will only burden company's operation cost, which will not be favourable for their business (2).

Various references recommend reverse logistics (RL) as one of the solutions to manage e-waste issue. RL in the e-waste management is the series of activities, including re-delivery system of damaged or unused electronics products from its consumption points back to the producers. One of the research areas that need to be developed is the reverse network and facility location problem. E-waste treatment facility location need to be decided in order to find optimum e-waste collection from consumptions points of final consumers with minimum total cost (3). Site selection decisions are generally used to determine the best location for plant placement, warehouse, or other facility location. The basic problem in any facility location problem is how to allocate some location into several potential facilities which can minimize system cost (4). However, in its implementation, not all of the company have chance to develop a RL network due to their budged and operational constraints. In some case, e-waste management can be conducted by the third parties.

Based on previous argumentations, this paper developed e-waste treatment facility location problem that can minimize transportation distance from e-waste collection points to the allocated e-waste treatment facility. This paper proposed e-waste restoration process which started from the electronics service centre, as e-waste collection point, then systematically transported and taken to the e-waste treatment facility. This research aims to determine a new e-waste treatment facility location that can minimize driving distance of reverse collection problem. The result of this paper is expected to be useful for electronic company in determining their reserve logistic facility location that can minimize transportation distance.

2. Literature Review

In general, logistic activity is related to material movements from producers to consumers. Its reserve activity, which flows from consumers to producers is called reverse logistics (RL). RL is a set of planning, implementing, monitoring process of material flow (raw, semi-finished materials, finished goods or goods with expired life) and information flow related to the consumption points, in order to effectively and efficiently return those material to their initial point for re-processing, recycling purpose or appropriate disposal process (5). Rahman, & Subramanian (6) expressed that RL process is getting more attention by the increasing public awareness on environment conservation. RL creates supply chain material flow becomes a closed loop supply chain flow. One of the RL objective is to restore product values that cannot be used any more back to the producers, and as a form of company responsibility of their resulted products (7). In general, the reverse logistics and its relatedness to supply chain in forming the closed loop supply chain can be illustrated in Figure 1.

To support e-waste recovery, collection process of e-waste from consumers to producers is needed. The process must be managed as efficient as possible, to minimize the required waste management total cost. The management of electronic waste management is quite much discussed by previous researchers, Hanafi (8) examine the e-waste collection model based on several collecting scenarios through retailers, manufacturing, using third parties or through cooperation between parties.

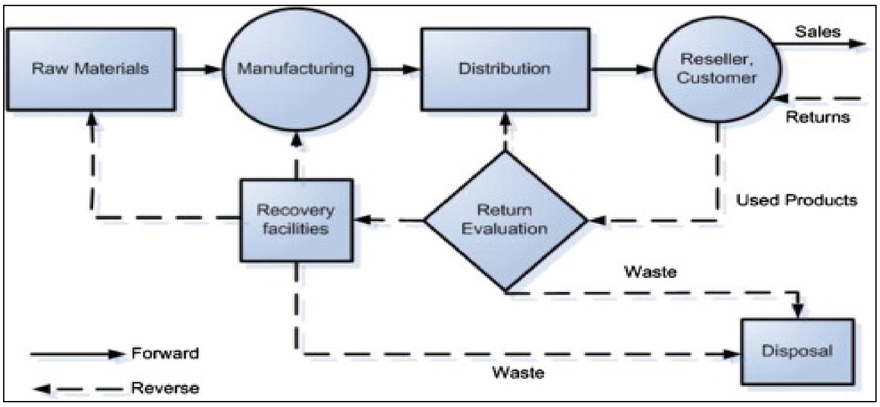


Figure 1. General description of RL process (7).

Fleischmann et al. (9) developed a reverse network by connecting; manufacturer; warehouses; consolidation centres; and customers. New products are shipped to customers via warehouses while returns products are shipped to recovery facilities via consolidation centres. Dowlatshahi (10) identified important factors related to financial profits in designing and applying the RL activities in restoring, refurbishing, remanufacturing and recycling process of e-waste that can provide profit for the company. Network design is one of the important strategic issues which may have long term impact on the performance of RL, including number of facilities, location and covered region, and their capacity or size (11). The location decision is a form of strategic decision making, since it involves large investment for development of facility and company may not always change the facility locations that have been built.

3. Gravity Location Model

Theoretically Gravity Location Model is based on coordinate selection of a location centre point that give the shortest total distance that can cover all of the location zones to be served. In the logistic field, the gravity model uses some basic assumptions, in this model transportation costs are assumed to be increased linearly proportional to the distance and transferred volume; the location of the source or market can be determined in a map with clear x and y coordinates (12). In the optimal determination of facility location (x, y), center of gravity method was used to minimize the total transportation distance. The location of facilities was calculated by the following formula:

$$x_{0n} = \frac{\sum_1 \frac{C_1 V_1 X_1}{J_1}}{\sum_1 \frac{C_1 V_1}{J_1}} \tag{1}$$

$$Y_{0n} = \frac{\sum_1 \frac{C_1 V_1 X_1}{J_1}}{\sum_1 \frac{C_1 V_1}{J_1}} \tag{2}$$

Where: xon, yon : x and y coordinates resulted in this iteration.
Ci : load in the i point
Xi : location of X position to the i point
Yi : location of Y position to the i point

4. K-means

Clustering as a tool of data grouping, it can be applied in various fields, such as facility location problem. K-Means is a non-hierarchy data clustering method dividing data into one or more clusters/ groups. The clustering aims to minimize the objective function set in the clustering process, in general to try to minimize the variation in a cluster and maximize variation between clusters.

Its application in facility location problem, is begins by calculating the Euclidean distance to mark the distance equation between each cluster. The grouping in this method is done based on the smallest distance between the object and the cluster centre. K-means algorithm is done with the following steps: Determine in advance the number of clusters desired; specify the members of each cluster at random; calculate the value of centroid. Calculate the distance between each point and both centroid values; perform the grouping by selecting the closest distance between each point and both centroid values. If there are previous cluster members moving the cluster, if there are no previous cluster members moving the cluster, then the grouping process is complete (13).

5. Clark-Wreight Saving Algorithm

One of the conceptually simplest heuristics algorithm for the vehicle routing problem (VRP) is Clarke and Wright's Savings Algorithm. The algorithm calculates all the savings Sij between customers i and j. Assuming that c_{i0} is the cost of travelling from the depot to customer i and c_{ij} is the cost of travelling from customer i to j. Clarke and Wright algorithm solve the CVRP by computing the savings from Sij = $C_{i0} + C_{0j} + C_{ij}$ for i,j =1,…, n while i ≠ j, then rank the savings S_{ij} in descending order. Next, create the savings list, start from the topmost entry in the list (the largest S_{ij} value). For the savings under consideration (S_{ij}), include link (i, j) in a route if no route constraints will be violated through the inclusion of (i, j). If neither i nor j have already been assigned to a route, then a new route is initiated including both i and j. If exactly one of the two points (i or j) has already been included in an existing route and that point is not interior to that route, then the link (i, j) is added to that same route. If the point is interior and not violating the capacity then adds (i, j) to the same route. If it's violating the capacity make a new route with the point (customer) i. If both i and j have already been included in two different existing routes and neither point is interior to its route, then the two routes are merged by connecting i and j. After that, if the savings list Sij has not been exhausted, repeat the calculation processing the next entry in the list; otherwise, stop (14).

6. Methodology

The data needed in this research is the location of e-waste collecting point (authorized service centre) in DKI Jakarta area. The e-waste collecting point is considered as the starting point of the RL, which then be searched for the minimum distance connecting collecting point to the e-waste treatment facility. The geographic location used is this paper was the latitude and longitude position of each authorised service centre and driving distance between those locations was obtained from the Goggle map. Electronics company's authorized service centre act as e-waste collection point.

Distribution of location of authorized service centre (collection point) is presented in Figure 1. Research Limitation and Assumption, this research is conducted with the following limitations and assumption:

- The electronic products included in this research is consumer goods or home appliances.
- Initials point of e-waste collection is the authorized service centre of electronic equipment.
- Transportation cost between collecting point and treatment facility is equal to the distance.
- There is unlimited capacity of RL e-waste treatment facilities.

Based on 35 collection points data (location coordinate and e-waste weight in each point), e-waste treatment facility location is determined. First, collecting points was clustered into one or more group, using K-means clustering algorithm. In each cluster facility location is determined using Center of Gravity location model. Once the coordinate of treatment facility location is determined, collection cost is calculated, by only considering collection distance from the treatment facility to the collection points for each cluster. The total collection distance was calculated by optimizing collection routing using Clarke and Wright's Savings Algorithm.

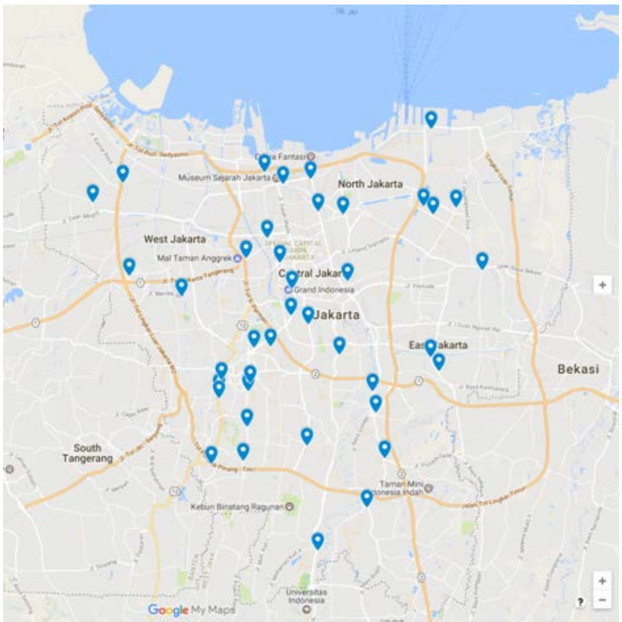


Figure 2. Electronic service centre as e-waste collecting point

7. Scenario Development

The models developed in this paper were developed in three scenarios. First, only one treatment facility will be built, the treatment facility will serve all the collect e-waste from all the collecting points. In the second scenario, there will be multiple treatment facilities, all the collecting point will be clustered into several groups, based on collecting driving distance. The number of an optimum clusters was decided by clusters minimum total distance. The third scenario consider government regulation to locate all industrial activities in dedicated industrial or warehousing area/park location, including e-waste treatment facility, in compliance with regional planning and environmental regulation.

7.1. First Scenario

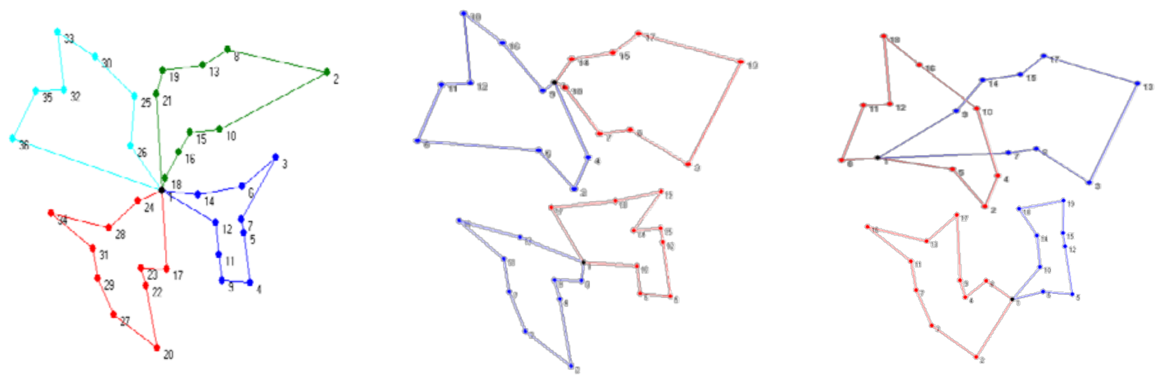
In this scenario, the model was built in two stages. First, e-waste treatment facility location was decided by using center of gravity approach. Once, the location was decided, routing collection was constructed using clark-wreight saving algorithm. It is found that e-waste treatment centre will be located at coordinate 6°13'23.9"S 106°49'52.8"E, which is located around Karet Kuningan. The total distance to cover all e-waste collecting points is 237.25 km. Total distance was retrieved from Google maps based on driving distance.

7.2. Second scenario

In this scenario, the model was built in three stages. First, e-waste collections point was clustered into several group using K-means algorithm to obtain minimum distance from treatment facility. After the group constructed, treatment facility location was calculated using centre of gravity approach. Once, the location was decided, routing collection was constructed using clark-wreight saving algorithm. It was found that optimum number of cluster was 2 cluster; South cluster and north cluster. Each cluster will be assigned into its treatment facility which located at coordinate 6°16'00"S 106°49'30"E which is located around Kemang Timur and 6°09'01"S 106°50'31"E is located around Kemayoran. The total driving distance to cover all e-waste collecting points is 123.99 km for the first cluster and 93.49 km for the second cluster or 217.48 km in total.

7.3. Third scenario

In this scenario, location of e-waste treatment facility was already known, as government regulation to build industrial facility only at Dedicated Industrial Estates. Once, the location was decided, routing collection was constructed using clark-wreight saving algorithm. There were two industrial or warehousing estate that is suitable as e-waste treatment facility location. First treatment facility is located near Cilandak at 6°17'34"S 106°48'46"E and the second is located near Pulo Gadung at 6°11'30"S 106°54'40"E. The total driving distance to cover all e-waste collecting points is 247.31 km for the first cluster and 105.12 km for the second cluster or 142.19 km in total.



(a) (b) (c)

Figure 3. Collection routing based on three scenario. (a) First scenario routing. (b) Second scenario routing. (c) Third scenario routing

8. Conclusion

E-waste treatment facility location in Jakarta, can be solved using simple algorithm with several steps. The location problem was solved in three steps as the following; collecting points clustering using the k-means algorithm, determining treatment facility location using the gravity centre model and e-waste collection routing using Clarke and Wright's Savings Algorithm. Considering driving distance only, using multiple treatment facilities will be more beneficial compared to single and locating treatment facility in dedicated industrial area. In order to maintain environmental issue, the government needs to force companies to locate their facility in dedicated industrial area, by giving incentive to attract company, since the driving distance is less beneficial than the single and multiple treatment facility scenario. Further research is needed in e-waste management and reverse logistics.

9. Reference

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