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Logistics Network Design for Electronic Waste with Community Issue Added

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Abstract. Reverse logistics hold the important key to collecting electronic waste. Problem that always occurs in reverse logistics is the expensive cost needed to access some route. One of the reasons it happens was the community issue in certain area with different approach and cost. Electronic waste itself is a hazardous substance that needs to be treated differently. Some regions only have storage permit for seven days, while few have the rights to process the electronics waste. It means that electronic waste needs to be transferred from one region to other while passing through the area with community issue cost. Using linear programming, determine the efficient route for reverse logistics in Indonesia will possible. A collection center will be placed in several regions in order to support fulfillment of capacity. Meanwhile, the collection center itself will reduce the community issue involve in operational cost of armada. Efficient route has been found in Indonesia following the capacity constraint in each region such as from Bandar Lampung consolidation to Bekasi processing plant.

1.  Introduction

Electronic waste is another type of hazardous materials that needs to be taken seriously. Leakage and risk of contamination is one of the problems that occur when the hazardous material needs to be moved. European Commission account the electronic waste into several categories that is applies after 15 August 2018 for newest category and applied from 13 August 2012 to 14 August 2018 for existing category [1]. Different categories needs to be handle properly, refers to Table 1 which shows that there are ten categories with different time constraint

| No  | Existing Category           | Newest Category          |
|-----|-----------------------------|--------------------------|
| 1   | Large household appliances  | Temperature exchange     |
| 2   | Small household appliances  | Screen and monitors      |
| 3   | IT and telecommunications    | Lamps                    |
| 4   | Consumer equipment          | Large equipment          |
| 5   | Lightning Equipment         | Small equipment          |
| 6   | Electrical tools             | Telecommunication        |
Collection and distribution process is one of the main concerns to minimize the environmental issue. Moreover, in some cases the electronic waste cannot be stored for more than seven days in countries such as Indonesia [2]. As one of the 4th largest human population, it is accounted that the number of electronic waste is also increasing exponentially. While Indonesia also holds a biggest logistics cost in the world, accounted for its 25% nation GDP [3]. Another challenge in Indonesia is community issue, when logistics provider needs to paid certain amount of money to enter or leaving the area. Commonly known also as illegal tax, it is estimated that community issue holds 17% from total logistics cost. Taken into micro view, it is concerned that Indonesia has its own challenges to tackle the community issue. Many of community issue in Indonesia usually occur can be solved using sea transportation.

Unfortunately, not all of the logistics connection can be solved using sea transportation. In some cases, it is still needs using trucks for its transportation because of the flexibility. Refers to electronic waste problems, it is obviously to use the trucks because of the time constraints regulation in Indonesia. Still, the community issue gives its uniqueness to transshipment problem for not only the efficient route possible for the electronic waste logistics but also a cheapest possible way to minimize the community issue. Different from another trucks routing problem in domestic waste, the electronic waste is also valuable goods for informal sector which attracting more community issue along the route [4].

2. Literature
Reverse logistics network design as one of system for collecting electronic waste needs to be considering in Indonesia. As one of the largest maritime nation in the South East Asia, it is need to be accounted that less transit points could be a game changer. Reverse logistics network for electronic waste can be described as a weighted graphical represented with nodes and arcs. One of the nodes is the starting point where electronic to be collected to the other transit nodes. For the last nodes after transit nodes is processing center nodes where electronic waste gathered from multiple collection point via transit will be processed. Each arcs is associated a value of distance between nodes. When it comes to reverse logistics, it is needed to be accounted for amount of delivery capacity cannot exceed the vehicle capacity. Table 2 shows different kind of previous research in reverse logistics network design.

| Author | Country | Approach | Advantages |
|--------|---------|----------|------------|
| [5], [6], [7] | Turkey | Mixed integer linear programming | Optimum storage location |
| | | | Lower transportation cost & more collection point when fixed cost is low |
| | | | Able to determine the best fit location for processing plant in three major cities based on multi-period cycle |
| [8] | Iran | | Capture the best fit location for collecting and capacity for processing plant |
Refers to different kind of previous research and characteristics, the reverse logistics network for electronic waste in Indonesia can be solved using simple linear programming.

3. Methodology
Using simple linear programming, route and cost in reverse logistics network design can be solved and minimized. Community issue added in transportation cost with different amount added in every route. Model described on Figure 1 consists of seventy four cities in Indonesia as a collection point for electronic waste. Collection center with seven cities also implemented in model to support the three major point for processing center that already given permission to processed hazardous waste in Indonesia.

![Figure 1. Reverse logistics network in Indonesia](image)

Based from the model purposed it is considered rational to stored electronic waste from collection point in collection center. In order to minimize amount of community issue needs to be paid by making fewer shipment from collection point to processing plant with bigger vehicle capacity than vehicle used for collecting from collection point. By doing so, the more community issue cost will be minimized.

Moreover, the objective function for reverse logistics network shown on equation (1)

\[
Min \sum_i \sum_j C_{ij} \times X_{ij} + \sum_j \sum_k C_{jk} \times X_{jk}
\]  

(1)

With index for supporting the objective function below
- \( i \); Collection point, \( i = 1,2,\ldots,74 \)
- \( j \); Collection center, \( j = 1,2,\ldots,7 \)
- \( k \); Processing center, \( k = 1,2,3 \)

Also using variable shown below
- \( X_{ij} \); number of electronic waste transported from collection point \( i \) to collection center \( j \) (tons)
- \( X_{jk} \); number of electronic waste transported from collection center \( j \) to processing center \( k \) (tons)

Parameter for supporting the equation:
- \( M_i \); Electronic waste production / week from collection point \( i \) (tons)
- \( N_j \); Collection center \( j \) capacity / week (tons)
- \( O_k \); Processing center \( k \) capacity / week (tons)
- \( C_{ij} \); Transportation cost from collection point \( i \) to collection center \( j \) (Rp)
- \( C_{jk} \); Transportation cost from collection center \( j \) to processing center \( k \) (Rp)

Constraints also needed to be added in order to balancing the equation:

\[
\sum_j N_j \geq X_{ij} \quad \forall \ i, j \quad (2) \\
\sum_i M_i \geq X_{ij} \quad \forall \ i, j \quad (3) \\
\sum_j N_j \geq X_{jk} \quad \forall \ j, k \quad (4) \\
\sum_k O_k \geq X_{jk} \quad \forall \ j, k \quad (5) \\
\sum_k O_k = \sum_j N_j \quad \forall \ j, k \quad (6)
\]

From constraint, equation (2) needed for balancing the capacity in collection center \( j \) and it also implied on equation (3) for balancing number of electronic waste transported to collection center \( j \) does not exceeded the weekly amount from collection point. Balanced equation also shown from equation (4) in order to constraint the capacity in processing plant. For equation (5) and (6) needed to balance the total amount of electronic waste collected, stored, and processed every week.

4. Analysis
Route for electronic waste in Indonesia especially with fewer community issue cost added in certain area can be considered an efficient route. For example, route on Figure 2 from collection center in Bandar Lampung city to Bekasi in West Java region as a nearest possible processing plant after Tangerang already fulfilled its capacity.

![Figure 2. Bandar Lampung route to Bekasi](image)

Fewer transit points also occurs on east corridor of Indonesia such as Jayapura, Ambon, and Tual route to Surabaya collection center with total 65 tons distributed directly from its collection point. It is considered logic and gaining advantages to minimize the total cost for transit. In other words, fewer transit points to Surabaya make it more efficient route to fulfill the processing center Bekasi. More about east corridor route amount and transportation cost shown on Table 3 below.
Table 3. East corridor route

| Collection point | Jayapura | Ambon | Tual | Transportation cost |
|-----------------|----------|-------|------|---------------------|
| Amount (tons)    | 20       | 25    | 20   | Rp. 118,415,667     |
| Collection center | Surabaya | -     | -    |                     |
| Amount (tons)    | 65       |       |      | Rp. 21,658,091      |
| Processing center | Bekasi   | -     | -    |                     |
| Amount (tons)    | 65       |       |      |                     |

5. Conclusion
Using linear programming, reverse logistics network in Indonesia for electronic waste can be obtained. Efficient route occurs in east corridors of Indonesia to minimize the transit points by shipping electronic waste directly to Surabaya collection center. There are also efficient route from collection center in Bandar Lampung to ship the electronic waste to Bekasi when Tangerang processing center capacity has been exceeded. Further research needs to analyze the community issue as a valid variable rather than just amount that needs to be added in transportation cost.

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