The Routing of Hazardous and Toxic (B3) Medical Waste Transportation Using Network Analysis (Case Study: Primary Health Care Services, Depok, Indonesia)

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Abstract. The hazardous and toxic (B3) medical must be managing carefully. The B3 medical waste management is a series of operations, including the collection, storing, transporting, processing, recycling or disposal, and monitoring of B3 waste and the disposal of the products of such processing. The process is very important because several categories are dangerous and toxic. Moreover, Solid medical waste can contain infections, sharp objects, drugs, cytotoxic, chemical, radioactive, pressurized containers, and have a high heavy metal content. This paper is aim to recommend the B3 medical waste transportation system for primary health care service (PHCS) and institutions related. The good of management and effective transportation are needed because it cannot endanger the increasingly of the crowded population. The data were collected in 11 of PHCS using survey and questionnaire. The point survey was processed by Google Earth/Maps and analyzed using ArcGIS. The statistic method was used to analyze the questionnaires which collected from 35 of PHCS. Based on the results, the mean value is between 4 and 3.9. It is represented that 11 PHCS have worked using waste transportation properly. Some of the PHCS was using the third party for managing the waste medical. Hence, more 37% from 13 PHCS transporting the material to the last pool of waste every day. Whereas the other (46% from 16 PHCS) carried out once a month, and 8 PHCS (23%) done twice in a month. Only 1 PHCS (3%) transported once a week. Therefore, we recommended the 13 best route for medical waste transportation using network analysis.

Keywords: B3 Medical Waste Management, Network Analysis, Primary Health Care Services.

1. Introduction

According to [1] Indonesia has a commitment to the processing and management of the waste program. It is stated on Law 32 in 2009 concerning of the protection and management of the environment [2]. Actually, the process and management of B3 waste have been declared since 1994 by Government Regulation No. 19 [3]. Currently, only 10 cities have sewage treatment plants, i.e.: Balikpapan, Banjarmasin, Bandung, Cirebon, Jakarta, Medan, Prapat, Surakarta, Tangerang, and Yogyakarta. Meanwhile, B3 medical waste management should be handled by the city (companies), PHCS, institution, and government. Primarily, it is collected locally by PHCS, then it is loaded onto a truck of companies to a ‘Tempat Pembuangan Akhir (TPA)’ or dumped [1]. The B3 medical waste (B3MW) is a material that directly or indirectly, can pollute, damage the environment, harm the environment, and health of humans. Other laws related to B3MW are Government Regulation No. 18 of 1999, No. 85 of 1999 and Act No. 18 of 2008. These laws govern the treatment of hazardous
B3MW, but there is still limited implementation. B3 is a primarily hazardous waste. It has to be dumped at the point of manufacture or either disposed of via incinerators on-site at PHCS (medical facilities) or via registered waste companies. Nowadays, it has to get attention seriously because B3 solid medical waste could be contained of infectious, pathological, sharp, pharmaceutical, cytotoxic, chemical, radioactive, pressurized, and has a high heavy metal content. It is declared on Decree of the Minister of Health No.1204 of 2004 [4].

Depok is a city which surrounding of the main city Jakarta. It consists of 11 sub-districts, where each sub-district has several types of health facilities such as primary health care services (PHCS). Currently, Depok has a total of 35 PHCS units, consisting of 11 technical implementation unit and 24 functional implementation unit [5]. In managing the B3MW, Depok must obey to [2] that “every person who produces B3 waste must carry out the management of B3. If everyone is unable to manage B3 waste, it must be taken by other parties”. Therefore, the Indonesian Ministry of Environment and Forestry Regulation enact No. 56 of 2015 concerning "Procedures and Technical Requirements for the Management of Hazardous and Toxic Waste Materials from Health Service Facilities" [6] [7]. Then, the Depok City Government enact to issue a Regional Regulation No. 3 of 2013 concerning "Guidelines for the Protection and Management of the Environment" [8]. But, in this study, we focused on the B3MW transportation system. The vehicle route of transportation is ineffective and not optimal to handle the 35 points of produced B3MW.

Refer to [9] it is possible to do route optimization for transportation system by select the best path, helping in time efficiency, for city administration and management according to the statuses of metropolis. The vehicle route problems have been studied for various problems such as solid waste, beverage industry, and newspaper distribution, and handled through detailed optimization techniques. Mostly, the GIS method is used in vehicle route planning for the collection of urban recycled waste materials. It significantly simplifies the processing of large sets of data, the location of collection and distance matrix calculations [10]. The shortest path model is used to optimize garbage collection/transport process using Route View Pro software. It is comprised of GIS elements such as numeric lines, demographic distribution, container distribution and the amount of solid waste production. Based on [11] the route is optimized compared to the current route, and it’s claimed that 3.0% and 17.0% in collection times and 5.5% and 12.5% in travel distance. The development of an optimal route creation scheme for waste disposal involves determining the number of selection criteria. One of the optimal GIS route models based on parameters such as waste generation, road network, and type of road, storage, and garbage transport vehicles. The routes are developed and used to track minimum cost/distance collection paths, and its effects for transporting solid waste to landfill [12]. We believed, the utilization of GIS and Global Positioning System (GPS) are able to capture and analyse spatial data which known and developed the best routing in the management of B3MW. Thus, the information about the geographical location of the solid waste collection will help the decision making on B3MW management. It is including the planning route of the collection, cleaning of garbage, and placement of collection locations. By providing maps, this paper is aims to give inputs for stakeholders related to the city's garbage system especially informal waste disposal facilities[13].

2. Materials and Methods
The method of survey was conducted to each of an object/site. Then, we distributed questionnaires to each of PHCS (namely Pancoran Mas District, Beji District, Sukmajaya District, Cimanggis District, Tapos District, Cilodong District, Limo District, Cinere District, Sawangan District, Cipayung District, and Bojongsari District). It has to fill out by the represented person. The questionnaires contained questions about the existing conditions of the location and routing transportation of B3MW to the final location. The PHCS coordinates are pointed by Google Earth or Google Maps and converted into ArcGIS software. Then, it locations were compared to Depok City Regional Development Planning Agency. Spatial analysis with Geographic Information System (GIS) can be an excellent alternative to assist the decision-making process [13], [14]. Afterward, the network
analysis feature was used to determine the fastest of route path. This activity referred to “the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.56/Menhk-Setjen/2015 concerning Procedures and Technical Requirements for the Management of Hazardous and Toxic Wastes from Health Service Facilities”. Next, the pathway can be continued by determining the best paths based on restrictions in accordance with the existing provisions.

The data questionnaires were analyzed using statistics method (qualitative and quantitative). It contained information on the implementation of B3MW management activities in 35 PHCS. The qualitative descriptive method is carried out to describe and explain the condition of variables contained in the object of research. Meanwhile, the quantitative descriptive method is used to determine the relationship between variables. The mean value is conducted by observing the respondent's answers. It used qualitative descriptive and explained in sentences. According to Furchan (2004), descriptive research has characteristics that tend to describe a phenomenon as it is by examining it regularly, prioritizing objectivity, and being done carefully.

ArcGIS Network Analyst has the ability to find the path that has the least impedance. It also has the ability to create and analyze networks datasets. This extension is made by using several parts of the ArcGIS namely ArcCatalog. It can create network datasets. ArcMap will do analysis and ArcToolbox will do geoprocessing process. The wizard of ArcCatalog makes it easy to create a dataset from a geodatabase or shapefile. It also will help to identify the feature class to be used, set rules in the network and identify attributes in the network (ESRI, 1998). Network Analyst ArcGIS can find the best path from one location to another or find the best way to visit several locations. The location can be determined interactively by placing points on the layer, by entering an address or by using a point in the features that exist in the class feature.

3. Results and discussions
Based on data analysed, 23 PHCS of 35 (66%) in Depok are working with PT Arah Environmental Indonesia in transporting B3MW. This company has permission from the Ministry of Environment and Forestry as well as the Ministry of Transportation. Their vehicles transportation is equipped with calibrated scales, cameras, and GPS systems in the transporting car.

3.1 Transportation of B3MW at Depok
We found that in general PHCS in Depok had carried out the transportation of B3MW well. This is indicated by the majority mean value of 4 and the smallest of 3.9. In addition, the new bags will replace the full bags with smooth and maximal. However, some PHCS in Depok is not collect B3MW every day. It can cause danger such as vomiting of patients. Therefore, it should faster collect and get treatment of process. But, most of PHCS does not have an equipment to move the B3MW from parts to parts which is resistant to scratches and sharp objects. Even B3MW has to be managed carefully and it requires a scratch resistant tool such as a syringe, scalpel, broken glass equipment. This equipment is needed for transporting B3MW and it will make the work more effective and efficient. Moreover, an easy-to-clean tool is needed to reuse next time.

In addition, several PHCS never cleaned the tools when it used in moving B3MW from parts to sections every day. However, the equipment must be clean in accordance with hygiene and health requirements. It will cause harm to health. Thus, the completeness of the officers or personnel in process storing is not provided using the specific clothes of occupational health and safety standards. This condition must be considered with the standards set by the government. For handling the B3MW, PHCS was collaborated with third parties for transporting into the location of the dump. Some PHCS uses a motorbike to transport it or ambulance vehicle. Of course, this transportation can pose a risk. They must use the specific vehicle with standardization as mention of regulation.

Unfortunately, the frequency of transport is determined by the main of PHCS. This is caused by a limited capacity of storing B3MW in main PHCS. Otherwise, the scheduling of loading vehicle into dumped is mentioned by third parties. In this case, the third parties are represented by PT Arah Environmental Indonesia. Mostly of 35 PHCS were cooperating with this company. The route of
transportation has been known by PHCS and institution of Environmental Office Depok. In one time the company loads B3MW for 3 PHCS regarding waste produced in a small amount. The truck routed to the pool using the road of Jonggol, Cileungsi, and Bogor. Next, this B3MW transported to PT Wastec International (the recycle and disposal of manufacturer). It is located on Jl. Australia II Kav 1/2 Region, Cilegon, Banten. Next, the frequencies of transportation of B3MW is showed in Table 1.

Table 1. Frequency of Transportation of B3MW

| NO | Transportation Frequency | PHCS | %  |
|----|--------------------------|------|----|
| 1  | 1 day 1 time             | 13   | 37%|
| 2  | 1 day 2 times            | 1    | 3% |
| 3  | 2 days 1 time            | 3    | 9% |
| 4  | 1 week 1 time            | 11   | 31%|
| 5  | 1 week 2 times           | 1    | 3% |
| 6  | 1 month 1 time           | 1    | 3% |
| 7  | When full                | 5    | 3% |
|    | **Total**                | **35**| **100%**|

From Table 1, it is known that the biggest percentage is 37% (13 PHCS) on one day one time. It is followed by 31% (11 PHCS) in once a week. It means that the frequency of transport varies by PHCS based on the volume of B3MW (Figure 1.). Next, the frequencies of third-party transportation are shown in Table 2.

Table 2. Frequency of Transportation of B3MW by Third Party

| NO | Freight Transport B3MW Frequency | PHCS | %  |
|----|----------------------------------|------|----|
|    | Transport by Third Party         |      |    |
| 1  | 1 week 1 time                    | 1    | 3% |
| 2  | 1 month 2 times                  | 8    | 23%|
| 3  | 1 month 1 time                   | 16   | 46%|
| 4  | No answer                         | 10   | 29%|
|    | **Grand Total**                  | **35**| **100%**|

Figure 1. Frequency of transporting B3MW from medical rooms to the final place of disposal.
From Table 2, it is known that 46% (16 PHCS) were transported once a month and its followed by 8 PHCS (23%) in one month twice and 1 PHCS (3%) in once a week and 29% of respondents did not answer (Figure 2).

![Figure 2](image)

**Figure 2.** The frequencies of transportation B3MW by a third party

We assume that the frequency of transportation of medical hazardous waste by third parties has been carried out well in Depok. The highest frequency by third parties is in every once a month. In accordance to Government Regulation No. 101 of 2014, “the storage of B3 waste does not exceed 90 days from the time B3 waste enters the dumped”. Therefore, medical hazardous waste management in Depok is good enough because the majority of storage is placed in PHCS not more than 90 days. It was immediately transported by third parties to the disposal or dumped.

### 3.2 Path Making and Best Path Selection Using Network Analyst

The next stage is making paths and selecting the best paths with ArcGIS Network Analyst. In this stage, the road digitized first by tracing the existing map called a polyline. This path or polyline used to analyze objects. The distance from the road is calculated using the formulas in ArcGIS as well as travel time. The results of the data are needed in making the best route, then it analyzed using the Network Analyst by route analysis. The optimal route has two or more points passed based on distance, time, or other indicators. The route analysis is depicted in Figure 3.

![Figure 3](image)

**Figure 3.** Best Line Selection with Route Analysis
Figure 3 is presented the checking the path on the map. If the paths found on the map, it can be passed by large vehicles. On some roads, it is tested and analyzed, which route is not passed by large vehicles. A careful truck check is an important process in making the best path, and to make it easier of an inaccessible road. The roads can be traversed using all types of vehicles including large vehicles. There are several roads that cannot be made because it is not passed by large vehicles.

The next process is to determine the scenario in making the path. The best path map shows that not always adjacent PHCS saw on the map. It can be directly connected with route analysis due to limited access road connections. On the first route, there are four PHCS from three sub-districts connected, namely Pengasinan, Kedaung, Cinere, and Limo. In total, we found 13 of the best routes and recommended to institution-related. The first scenario was carried out in the selection of the transport line from the Transporter Pool Truck to the two points of the PHCS (Figure 4).

![Transporter Location](image4)

**Figure 4. Transporter Location**

The transporter location is on Jonggol road, Cileungsi, and Bogor Regency. The second scenario, which has been approved and has permission from the Depok (namely East Kartika Clinic) is depicted in Figure 5.

![East Klinik Clinic](image5)

**Figure 5. The location of East Klinik Clinic as designated Collector B3MW of Depok**

According to East Kartika Clinic (B3MW collectors), it was found that 11 routes as the best route and 20 PHCS are served for transporting B3MW (Table 3).

| No. | Route Map | Description                                                                 |
|-----|-----------|------------------------------------------------------------------------------|
| 1   | ![Route Map](image6) | In one day, the East Kartika Clinic can serve 2 PHCS at once due to the distance. It is not too far away and the road conditions passed by large vehicles |
| No. | Route Map | Description |
|-----|-----------|-------------|
| 2   | ![Route Map](image1.png) | The route is used to serve 2 PHCS at once within one day. This is greatly facilitates and the transport time more effective. |
| 3   | ![Route Map](image2.png) | The route taken by Network Analysis shows to get to the Kemiri Muka Health Center to take a long way. This is because the roads that are close cannot be passed by large vehicles. |
| 4   | ![Route Map](image3.png) | The route is to the Kemiri Muka but it takes a long way because the conditions are not passed by a large vehicle. |
| 5   | ![Route Map](image4.png) | The service route in 1 day can get transportation in 3 health centers, namely Baktijaya, Mekar sari, pus. Cisalak pasar health center. |
| 6   | ![Route Map](image5.png) | The route to Pondok Sukmajaya. It is required a long way because the conditions are not passed by a large vehicle. |
| 7   | ![Route Map](image6.png) | The service route in 1 day can get transportation at 5 puskesmas namely Cimanggis, Bakti jaya, Sukamaju Baru, Villa pertiwi, Jatijajar health center. But because the route point cannot be right at the location of the health center, it indicates that the road to the health center is a road that cannot be passed by large vehicles. |
| No. | Route Map | Description |
|-----|-----------|-------------|
| 8   | ![Route Map](image1) | The service route takes in 1 day in 3 PHCS, namely Baktijaya, Mekar Sari, and Cisalak Market. |
| 9   | ![Route Map](image2) | The service route in 1 day can get transportation at 3 health centers, namely Beji health center, Cinere health center, Kedaung health center |
| 10  | ![Route Map](image3) | The service route takes in 1 day in 3 PHCS, namely Baktijaya, Cisalak Pasar, and Harjamukti |
| 11  | ![Route Map](image4) | The service route in 1 day can get transportation in 2 health centers, namely Bakti Jaya health center and Tugu health center |

4. Conclusion

Our study concluded that most of PHCS in Depok was managed the B3MW in a good manner. But, it still increases to achieve good environmental and public health. It is showed that mostly the frequencies of the truck loaded and vehicle for transporting B3MW into the dumped still using the main road of the city. This study recommended 13 the best path of routing transportation B3 Medical Waste. It should come to be concerning to PHCS, Institution related, Government, and the companies (who take the responsibility of transportation). Next, according to frequencies of B3 waste from the medical room to storage is dominated by 13 PHCS (37%). It will increase in every year and should anticipate regarding be crowded of Depok and Jakarta. Thus, the categories of PHCS will get to the level of the complex of services. All services of primary public health will pool in that place. We hope this research will impact the government as well as the institution related to managing B3MW carefully and properly. The future of study will examine the best route to predict the effective time consume in transportation.
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