PROPOSING AN EFFECTIVE ROUTE FOR TRANSPORTING SOLID WASTE USING GIS APPROACH

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Abstract. Transportation is one of the important elements in solid waste management. Effective transportation by selecting the shortest route can save time and cost in handling the waste. Thus, this paper presents a case study on deciding shortest waste transportation route from residential area to sanitary landfill in Kluang district handled by Solid Waste and Public Cleansing Management Corporation (SWCorp). The shortest transportation distance was determined using ArcGIS software on the basis of coordinate tracking, data collection for network analysis and fuel consumption estimation. The case study focuses on municipal solid waste collection routes from residential area in Kluang district to Ladang CEP 1 sanitary landfill and Seelong sanitary landfill. The study found that SWCorp could save up to 18% and 7.3% of fuel consumption per day by following the effective routes for transporting solid waste to Ladang CEP 1 sanitary landfill and to Seelong Sanitary landfill respectively. The findings could assist SWCorp saving management cost and also keep environment cleaner.

Keywords: Geographical Information System, Network Analysis, shortest routes.

1.0 Introduction
Solid waste management was quite primitive until the late 1970s. [1] State that solid waste management program in Malaysia was developed in phases. Nowadays, issues related to generation of solid waste become more popular due to increase rate of population and the quantity of waste generated [2]. At present, landfilling is the only method used for the disposal of municipal solid waste (MSW) in Malaysia which have been seated in each state, and most of the landfill sites are open dumping areas, which expose serious environmental and social threats [3,4,5]. Approximately 95 - 97% of wastes collected in Peninsular Malaysia are brought for final disposal at landfills while the remaining 3 to 5% are diverted to recyclers / re-processors and/or self-treated [6]. Therefore in order to cut transportation cost to sanitary landfill during waste collection, the shortest route from collection spot to sanitary landfill should be taken. The impact of
long distance of waste transportation will increase the use of fossil fuel consumption and time taken to arrive landfill area also be longer [7].

Three concessionaire companies, which are; Alam Flora Sdn Bhd who manages the central and east zones comprising the Federal Territory of Kuala Lumpur, Putrajaya, Pahang, Terengganu and Kelantan, SWM Environment Sdn Bhd, manages the southern zone that includes Johor, Melaka and Negeri Sembilan and Environment Idaman Sdn Bhd manages the northern zones of Kedah and Perlis [10,11]. On the other hand, Pulau Pinang and Selangor handle the waste independently [11,12]. The selected contractors will collect, store, transport, treat, and recycle all of the country's non-hazardous waste [11]. Toxic wastes handled by the Department of Environment in which all toxic wastes are contracted to Kualiti Alam Sdn Bhd for disposal at Bukit Nenas in Negeri Sembilan State [13].

Table 1 shows contractors in Malaysia that responsible to manage waste production according to their own region and operation coverage [10,11]. This research focused on municipal solid waste collection by SWM Environment Sdn Bhd in Kluang district.

Table 1: Contractors that responsible to manage solid waste association by region in Malaysia [10,11].

| Region                      | Contractor                  | Operation Coverage                  |
|-----------------------------|-----------------------------|-------------------------------------|
| Central and Eastern Peninsular Malaysia | Alam Flora Sdn. Bhd.        | Kuala Lumpur, Putrajaya, Pahang.    |
| Southern Peninsular Malaysia | SW Environment Sdn. Bhd.     | Johor, Negeri Sembilan and Melaka.  |
| Northern Peninsular Malaysia| E-Idaman Company             | Kedah, Perlis.                      |

This study will proposed an effective route for garbage truck from collection point to sanitary landfill in Kluang district Johor using Arc GIS Network Analyst. The Arc GIS Network Analyst used same method to identify effective route for MSW in Nagpur city, India [8]. Figure 1 shows the map of Johor state. The shaded area shows the Kluang district while the yellow tagging shows the landfill locations that involve in this research. SWCORP has appointed a private waste management service contractor to collect all the MSWs and dispose the waste [9].

Figure 1: Map of Kluang district and sanitary landfill location.
2.0 Scope and limitations
Below are lists of some limitations of determination the shortest routes for transporting solid waste by using Geographical Information System at Kluang district:

i. Routes characteristic such as width of the lane and speed limit for each route does not include in this research since the research only focus on the distance of the route.

ii. The results for transportation municipal solid waste in residential area in Kluang district to Ladang CEP 1 sanitary landfill and Seelong sanitary landfill area is only focus on waste handling by SWM Environment Sdn Bhd only.

3.0 Geographical Information System GIS
Geographical Information System (GIS) is the best tool to gain optimum distances and cost towards the solid waste management [14,15,16,17]. They have been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modelling and engineering [18]. According to [19] the system allows effective and efficient visual interpretation and display of results. A part from spatial modelling techniques, GIS may provide large economic and environmental savings through the reduction of travel time, distance, fuel consumption and pollutants emissions [14]. Therefore, this study will use GIS to determine the shortest routes for transporting solid waste at Kluang district and to develop database for road network and dumpsite in Kluang area. By using GIS technique, a single layer network operation was conducted to determine the optimum route for hauling waste to landfill.

4.0 Methodology
The research procedures involved the following three steps which are coordinate tracking, data collection for network analysis and fuel consumption estimation to determine the shortest route for transporting solid waste using GIS in Kluang District.

4.1. Coordinate Tracking
Application “One Touch Location” GPS from Android Smartphone were used to track the coordinate that can be used to map the actual location of landfill area in Google Earth’s. Figure 2 shows the coordinate tracking at Ladang CEP 1 sanitary landfill and Seelong Sanitary landfill. Thus, from this tracking, the coordinate at each landfill is 1°53’25.00”N 103°23’17.00”E for Ladang CEP 1 sanitary landfill while 1°39’41.00”N 103°43’16.00”E for Seelong Sanitary landfill. This coordinate used to validate the location of landfill area to disposed all waste from Kluang district.

![Figure 2: Coordinate tracking at landfill area.](image)

4.2. Data Collection for Network Analysis
After the coordinate of landfill location determined, the network analysis will been made using ArcGIS software. Figure 3 shows the flow chart of data collection for identify the shortest routes to transport solid waste in Kluang District.

![Figure 3: Flow chart of data collection.](image)

Data were collect through attribute data and spatial data. Figure 4 shows the attribute data that contain the detail of road name, carriageway traffic, routes direction, authority and length while the spatial data contain map of Kluang District.

![Figure 4: Attribute data and spatial data.](image)

After data have been collected, the data were used in Network Analyst tools to get the shortest distance from residential area to Ladang CEP 1 sanitary landfill and Seelong Sanitary landfill. The results for current distance were gained from SWCorp while the shortest distances gain from Network Analyst tools. Therefore the comparison distance between current and shortest distance are obtained.

4.3. Fuel Consumption Estimation
Fuel consumption estimation is based on the total distance for each routes that used to collect all waste from residential area in Kluang district to Ladang CEP 1 landfill and Seelong Sanitary landfill. The results for current distance were gained from SWCorp while the shortest distances gain from Network Analyst tools. Therefore the comparison distance between current and shortest distance are obtained.

In this study, garbage truck is refers to a truck specially designed to collect municipal solid waste and transfer the collected waste to a solid waste treatment facility such as sanitary landfill [20]. Therefore, waste collection process contains detail process from filling of containers to loading of the collection vehicle. Due to variety of residential, commercial, and industrial development, it is impossible to collect waste with just
A variety of collection systems are used with respect to municipal requirements. Each collection method has compatible container systems and vehicles with dedicated loaders [17]. Garbage trucks are classified in eight gross-vehicle-weight (GVW) classes. Gross vehicle weight means empty vehicle weight plus cargo weight. The classes were formulated over 50 years ago when truck transport was not very prevalent [20]. Therefore, Table 2 are used to convert, miles driven (mi/yr) from total fuel used (gal/yr) [20].

| Eight truck Classes (Body Type) | Miles Driven (mi/yr) | Number of Trucks | Total Fuel Used (gal/yr) |
|---------------------------------|----------------------|------------------|------------------------|
| Dump/Garbage                    | <40,000              | 20,535           | 46,014,662             |
|                                 | 40,000-60,000        | 3,797            | 35,481,756             |
|                                 | 61,000-80,000        | 4,872            | 65,079,191             |
|                                 | >80,000              | 7,233            | 145,494,922            |

SWCorp use 12 number of garbage truck to collect MSW in Kluang District. The model of garbage truck is Mitsubishi FUSO FM657JSRDG2 with Euro II engine using diesel. The gross weight for this truck is 16000kg. The coefficients are gain from Table 2. Thus, the coefficient value that used on fuel consumption for garbage truck is 0.591 litre/kilometer [19]. After that, the shortest distances for transporting solid waste from residential area to landfill area were determined. Then, total fuel consumptions using shortest distance were calculated and compared with actual total fuel used to collect and transfer the waste to landfill.

5.0 Results and Discussion

Data analysis based on data collection at two zones in Kluang district that only focus on waste collection at residential area by Solid Waste and Public Cleansing Management Corporation (SWCorp) to Ladang CEP 1 sanitary landfill and Seelong Sanitary landfill. Each zone is divided into six division for solid waste collection routes. Results for this research was obtained from the coordinate tracking and Network Analyst tools adapted from ArcGIS software. The amount of fuel consumption for current routes and shortest routes at Zone 1 and Zone 2 area are depend on the distance to transport the solid waste.

Figure 5 shows the result window that give the total distance for solid waste collection routes from residential area to Ladang CEP 1 sanitary landfill and Seelong Sanitary landfill area.
Figure 5: Distance from residential area to landfill area.

Figure 6: Percentage of shortest routes and fuel consumption at zone 1 for 1 day.
Figure 6 shows the percentage of shortest routes and fuel consumption at zone 1. Thus, from the result, the highest percentage saving for fuel consumption from residential Zone 1 to Ladang CEP 1 is route 6 which is 8.57%, while route 2 and route 4 does not have saving fuel consumption. The highest percentage saving for Zone 1 to Seelong Sanitary landfill is route 1 which is 2.07% while route 2 and route 4 have no saving fuel consumption.

![Percentage Of Shortest Routes And Fuel Consumption At Zone 2](image)

**Figure 7:** Percentage of shortest routes and fuel consumption at zone 2 for 1 day.

Figure 7 shows the percentage saving of fuel consumption when shortest routes is taken at Zone 2. The highest value of saving in fuel consumption is route 5 which is 16.52% to Ladang CEP 1 sanitary landfill while 6.01% to Seelong Sanitary landfill. However, route 3 and route 6 to Ladang CEP 1 sanitary landfill do not save any fuel. The same also happened to Seelong Sanitary landfill for route 2, route 3 and route 6. There are no fuel save for those routes because the shortest routes are similar with current routes. It shows that current route used are already shortest route to the landfill area.

![Percentage Saving Of Shortest Routes And Fuel Consumption At Kluang District](image)

**Figure 8:** Percentage of shortest routes and fuel consumption at Kluang District.
From Figure 8, the highest fuel consumption saving for transporting solid waste to Ladang CEP 1 sanitary landfill is route 5 which is 17.88% while the lowest percentage saving is route 4 which is 0.94%. The highest result for fuel consumption saving when transporting solid waste to Seelong Sanitary landfill is route 5 which is 7.28% while the lowest percentage saving is route 2 which is 0%. Thus, SWCorp can save up to 18% of fuel consumption per day by following the optimize routes for transporting solid waste to Ladang CEP 1 sanitary landfill. In addition, SWCorp also can save up to 7.3% per day of fuel consumption for transporting solid waste from Kluang district to Seelong Sanitary landfill.

6.0 Conclusion
From the analysis, its shows that the shortest routes at Zone 1 to Ladang CEP 1 sanitary landfill is route 6 and to Seelong Sanitary landfill is route 1. While for Zone 2 the shortest route to Ladang CEP 1 sanitary landfill and to Seelong Sanitary landfill is route 5. This study will assist SWCorp in reducing waste management cost.

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