GIS APPLICATION FOR UPDATING THE INFORMATION OF WASTE TRANSPORTATION IN LIEN CHIEU DISTRICT, DANANG CITY, VIETNAM

Tran Thi An[1], Le Ngoc Hanh[2] and Truong Van Canh[2]

[1]Faculty of Management Science, Thu Dau Mot University, Vietnam
06 Tran Van On Street, Phu Hoa Ward, Thu Dau Mot City, Binh Duong Province, Vietnam
Email: tranthian.gis@gmail.com
[2]Faculty of Geography, University of Science and Education, The University of Danang, Vietnam
459 Ton Duc Thang Street, Danang City, Vietnam
Email: lnhanh@ued.udn.vn, tvcanh@ued.udn.vn

ABSTRACT

Geographical Information System (GIS) has been widely used in many applications especially in geospatial data management. The main objective of this research is building a GIS database related to the municipal waste transportation in Lien Chieu District, Danang City, Vietnam. This GIS database includes the information about the traffic system and solid waste collection in Lien Chieu District was built based on the field surveys integrating with other referenced data sources such as OpenStreetMap (OSM) and data from local authority. These data were processed in a GIS environment to prepare for waste transported optimization through Network Analyst method in ArcGIS software. The optimal waste transportation route proposed from this study can save the travel time and distance compared to the current route. Especially for the forklift trucks, the waste transported time is reduced by nearly 40 minutes, traveling distance is reduced by about 14 kilometres and the number of transportation trips is also saver compared to the current route. This improvement will increase the efficiency of the waste collection process and reduce the environmental pollution in Lien Chieu District. Results from this study can be widely applied for solid waste management in other metropolitan areas where suffering high pressure of population as well as municipal waste growth.

Keywords: GIS database, network analyst, municipal waste, waste transportation, route optimization.

1. INTRODUCTION

Municipal solid waste (MSW) is one of the top concerns in many countries around the world. The problem of timely collecting and transporting solid waste from different sources to the collection centers in response to environmental pollution and urban beauty is an urgent need of many cities. A shortest waste collection and transportation strategy can effectively reduce waste collection and transportation cost (Swapan and Bidyut, 2015). This research aims to generate the GIS database related to the municipal waste transportation in Lien Chieu District which is currently a developing urbanized district in Danang City, Vietnam. It is observed that the amount of domestic waste is increasing along with the urban expansion and population growth (World Bank, 2018). Currently, Lien Chieu District is suffering about 160 tons of household waste per day and this amount of waste is forecasted about 280 tons per day by 2030 (Danang Urban Environment Company). In order to enhance the environmental situation as well as the urban beauty, the rapid movement of garbage from gathering points to the landfill sites while ensuring the efficiency of collection and transportation is a problem that needs to be studied and resolved. GIS combined with other analytical methods can be widely used in the waste management (Amirhossein *et al.*, 2013; Yadav Sk., 2013; Amjad *et al.*, 2016)

as well as optimization of waste transportation routes.

This study was conducted with the goal of building a GIS database for the purpose of optimization of the household waste transportation route in Lien Chieu District, Danang City, Vietnam. The traffic data including information about the route systems and their attributes were collected and standardized using the OpenStreetMap (OSM) application. Information about solid waste collection in Lien Chieu District was built based on the field surveys integrating with other referenced data sources. These data were processed in a GIS environment to prepare for waste transported optimization through Network Analyst method in ArcGIS software. The optimal waste transportation route proposed from this study can save the travel time and distance compared to the current route. Especially for the forklift trucks, the waste transported time is reduced by nearly 40 minutes, traveling distance is reduced by about 14 kilometers and the number of transportation trips is also saver compared to the current route. This improvement will increase the efficiency of the waste collection process and reduce environmental pollution.

2. METHODOLOGY

2.1 Study Area

The study area is Lien Chieu District which is a dynamic urban developing area of Danang City, Vietnam (Figure 1). This study area is also a hotspot of industrial as well as residential development. In accompany with the development process, the Lien Chieu District is also facing to a relatively large amount of solid waste. Regarding the waste transportation methods, there are two main methods in Lien Chieu District using forklift and compactor trucks in which transportation by forklift obtained 75 percent of the total collected waste volume of the study area. The authors had conducted tracking surveys of waste collection and transportation by using video camera recordings and GPS loggers, and collected the data on coordinates, transport locations (right of the road, left of the road or both sides of the road), transportation time, estimated waste volume, etc. These data are important sources for generating the solid waste GIS database and optimization of the waste transportation route for Lien Chieu District. This study focuses on building the optimal waste transportation route for forklift trucks which is the main vehicle using for waste collection in Lien Chieu District.
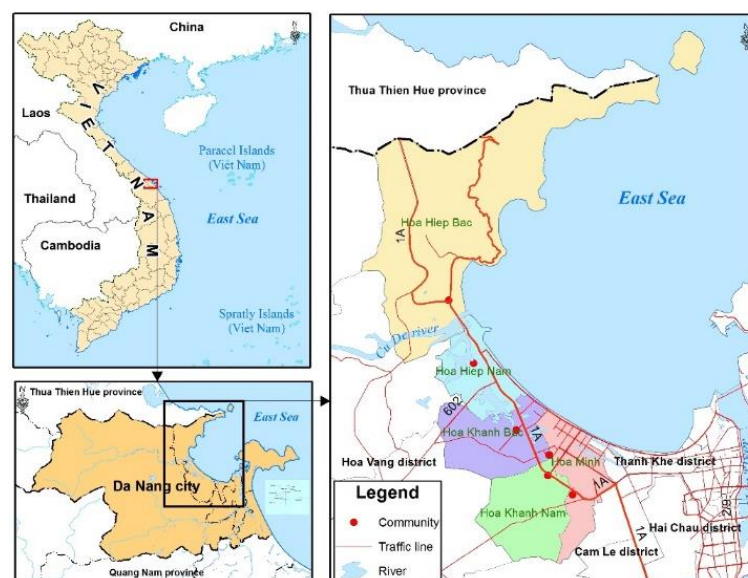

Figure 1. Overview of study Area.

2.2 Generation of GIS database

The OpenStreetMap data (Openstreetmap.org) which is a free and dynamic geospatial database was used to generate the traffic system map for Lien Chieu District, Da Nang City. Data collected on OSM is presented in vector which are in different formats (point, line, area) representing almost all spatial information about the real world. After collecting the road data from OSM, the study tried to extract the necessary traffic GIS data related to the construction of the waste transportation route such as roads, stops, obstacles, barriers, ... including both spatial and attribute information.

In addition, the traffic data collected from the local agencies was also utilized for validation of the road system. In this study, we extract data related to traffic of Danang City from the Department of Natural Resources and Environment, Department of Transport, etc. Subsequently, the filed survey data was also investigated as a supplement traffic data for OpenStreetMap (OSM). The road data on OSM sometimes lacks information such as road name, road type, traffic signs, etc. Therefore, updating the OSM data using field survey data is an effective solution to prepare the completed road system for the determination of the waste transportation route.

The data related to waste transportation includes the information on household waste, transportation vehicles and landfill sites. A field survey was conducted in the period from March 2020 to October 2020 in Lien Chieu area for the purpose of generation of GIS database related to solid waste transportation. In order to generate the data on waste gathering points, we have tracked the information on the location and volume of garbage as well as the collected time at each point in the Lien Chieu District with the help of video camera and GPS logger. The data on waste transportation means including the information on the type of vehicles, load capacity and operating time were also investigated in this field work.

2.3 Research workflow

The research workflow for generation of GIS database and optimization of waste transportation route for Lien Chieu District, Danang City is shown in Figure 2. The data on household waste and traffic system after being collected were standardized in both spatial and attribute information. In order to validate the spatial road data, the Topology tool in ArcGIS was used to identify the geometrical errors. Regarding the attribute data, the missing information on OSM data has been updated by using the supplemented data such as data collected from local authorities or field surveyed data. Subsequently, an application namely Network Analysis, was executed in GIS environment to generate the map of the optimal waste transportation routes in Lien Chieu District.

ESRI's ArcGIS Network Analyst extension allows users to perform complex calculations to solve the vehicle routing problems. The program performs analysis over a network of connected edges and decides fleet routing, travel directions, closest facility, service area, and location allocation (O'Connor, 2013). In addition, the Network Analyst allows the user to dynamically model genuine network situations, and hence facilitates finding the optimal route that is very important in solid waste transportation. Network Analysis is actually a tool to support fast and effective decision making for spatial analysis problems based on network systems such as: analyzing the shortest route, the optimal access, service delivery area, determining the nearest service facility, ... Network Analyst allows simulation of complex real-world network models with limited conditions such as one-way roads, forbidden roads, limits speed, time, vehicle limits, obstacles, ... In addition, the study also compares the proposed route with the current waste transportation one in the Lien Chieu area in order to evaluate the cost

efficiency.
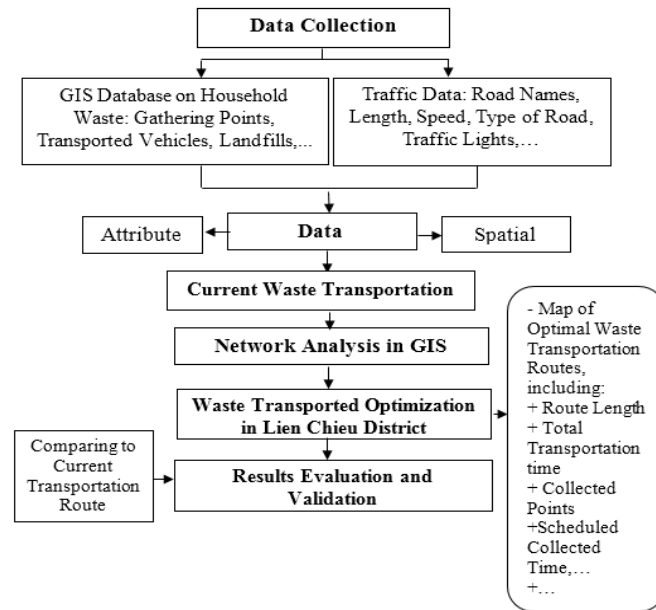
Figure 2. Study Workflow on Generation of GIS Database for Waste Transportation in Lien Chieu District

3. RESULTS AND DISCUSSIONS

3.1 GIS database for waste transportation in Lien Chieu

The traffic data is generated from OSM data combining with other supplemented data and transformed to the GIS format. The GIS database about traffic system in Lien Chieu District including both spatial and attribute dimensions has reflected adequately information for waste transportation in the study area. Based on the information about length and speed, the study calculated the travel time for each different road segment. In addition, traffic light data was also investigated in this study. The road system downloaded from OSM usually does not include all traffic light locations in the Lien Chieu area. In this case, the field survey data has been used to update information about these barriers of the waste trucks for the study area. In addition, the time for passing the traffic light was also modified in order to meet the requirement for Network Analysis.

Garbage data includes information about gathering points such as: the system of gathering locations, information of garbage trucks, landfill sites collected by field method. We have conducted a field survey to get information related to the waste collection such as order of points, type of bin, number of dustbins, estimated waste volume, collected time in the day, collected days of the week; transported location (on the right, left or both sides of the road), time to take garbage into the vehicle ... In addition, we also investigate the information of waste trucks in this area such as: vehicle, loading capacity, transported time of the day, ...Figure 3 shows the GIS database for determination of waste transportation route in Lien Chieu District that was generated from this study.
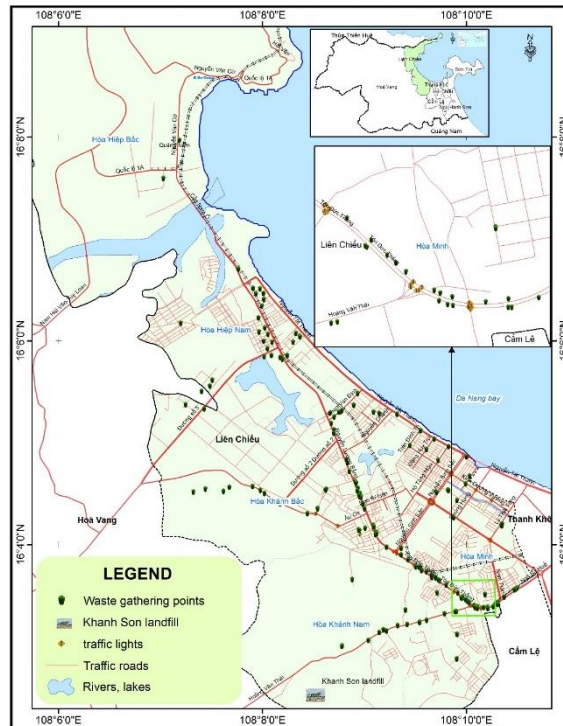
Figure 3. GIS database for building the waste transportation route in Lien Chieu District – Da Nang City

3.2 Generation of waste transportation map for forklift trucks in Lien Chieu District

3.2.1 Setting the parameter for Network Analysis

In this study, the waste transportation route was generated using the Network Analyst which is an extension in ArcGIS software that provides network-based spatial analysis including routing, travel directions, closest facility and service area analysis (Amirhossein *et al.*, 2013). There have been several studies on application of Network Analysis in waste transportation optimization (Amirhossein *et al.*, 2013; Apaydin and Gonullu, 2007; Phatsasi and Kampanart, 2018), however the results are still limited due to the parameter setting problem. This study experiences the method of using Network Analysis in generation of waste transportation route in Lien Chieu District, and proposed the optimal waste collection route.

The parameters for Network Analyst application in ArcGIS software includes the following key information: Orders (information about gathering points), Depots (information about the vehicle characteristics), Routes (information about transportation routes), Break (information about break time if any), Route Zones (information about the transporting area), Specialties (information about special points on the transportation route), Barriers (information about obstacles on the road including points, lines or polygons), etc.

The data about garbage gathering points (Orders) has the following main information requirements: the consuming time when transporting garbage on the vehicle, the time of waste collection in the day, the waste volume at each point and garbage is taken from the right or left of the road, or both sides of the road, ...The data of the vehicle characteristics (Depots) includes the following main information: start and end locations of the waste trucks on the route; start time, end time; driving rules (left, right or can run on both sides), ...Subsequently, the Routes data includes the following information: route name; starting point, ending point; the earliest start time and the latest one; load capacity; maximum number of stops; transportation time, etc.

As a result, we have built a completed GIS database of garbage transportation. This is

the important input data source for establishing the network analysis in GIS to determine the optimal waste transportation route in Lien Chieu District - Da Nang city. This study has focused on optimization of the waste transportation route for the forklift trucks which are the major collection means in Lien Chieu District.

3.2.2 *Current waste transportation map for forklift trucks in Lien Chieu District*

In Lien Chieu District, there are currently two transportation routes of forklifts denoted Lien Chieu A (LCA) and Lien Chieu B (LCB). In this study, we use the network analysis in GIS to reconstruct the waste transportation route for the forklift trucks based on investigating the route-related information such as: gathering location, waste volume, transportation time, ... The waste transportation route includes the following major information: trip order, starting time, ending time, place, order of transportation, amount of garbage, distance, etc. Results of generation the current waste transportation map for forklifts in Lien Chieu District using the Network Analysis application are shown in Figure 4.
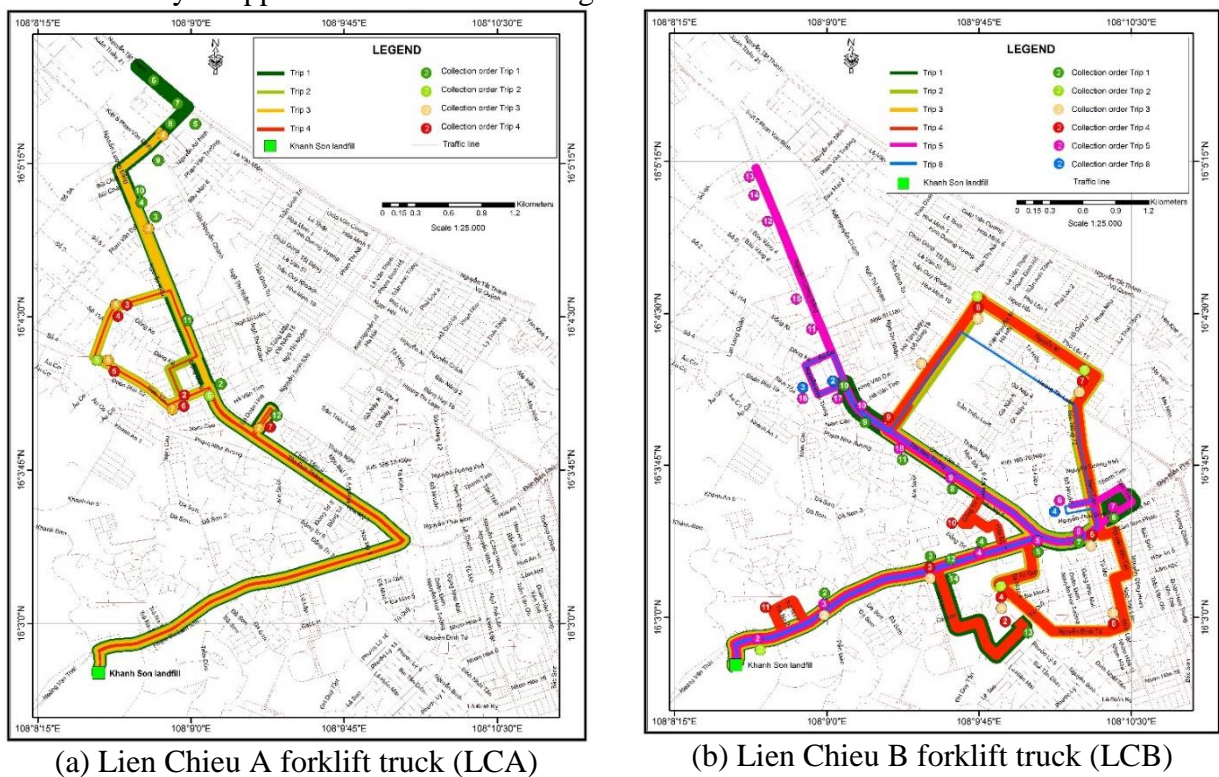

(a) Lien Chieu A forklift truck (LCA)   (b) Lien Chieu B forklift truck (LCB)

Figure 4. Current waste transport route map of Lien Chieu District, Danang City

3.2.3. *Optimization of the waste transportation route for forklifts*

The current waste transportation routes of Lien Chieu A and Lien Chieu B forklifts basically meet the needs of garbage transportation in the District. In this study, optimization of the current waste transportation route is the process of finding the optimal routes in case of the total waste collection volume of the forklift is not changed. In order to generate a better waste transportation route, we have adjusted the parameters on Network Analyst such as: transportation route, the amount of waste that can be collected at gathering points, Order of garbage transportation.

In this study, we tried to optimize the current waste transportation route based on the assumption that all the forklifts can load the maximum waste volume. In this case, we combined

the data of the LC A and LCB routes and break down the waste at gathering locations into smaller locations. The purpose is to increase the vehicle's loading capacity up to maximum volume. The results of optimal waste transportation for forklift trucks in response to the current waste volume of Lien Chieu District are represented in Figure 5 and Table 1.

(a) Lien Chieu A forklift truck (LCA))   (b) Lien Chieu B forklift truck (LCB)
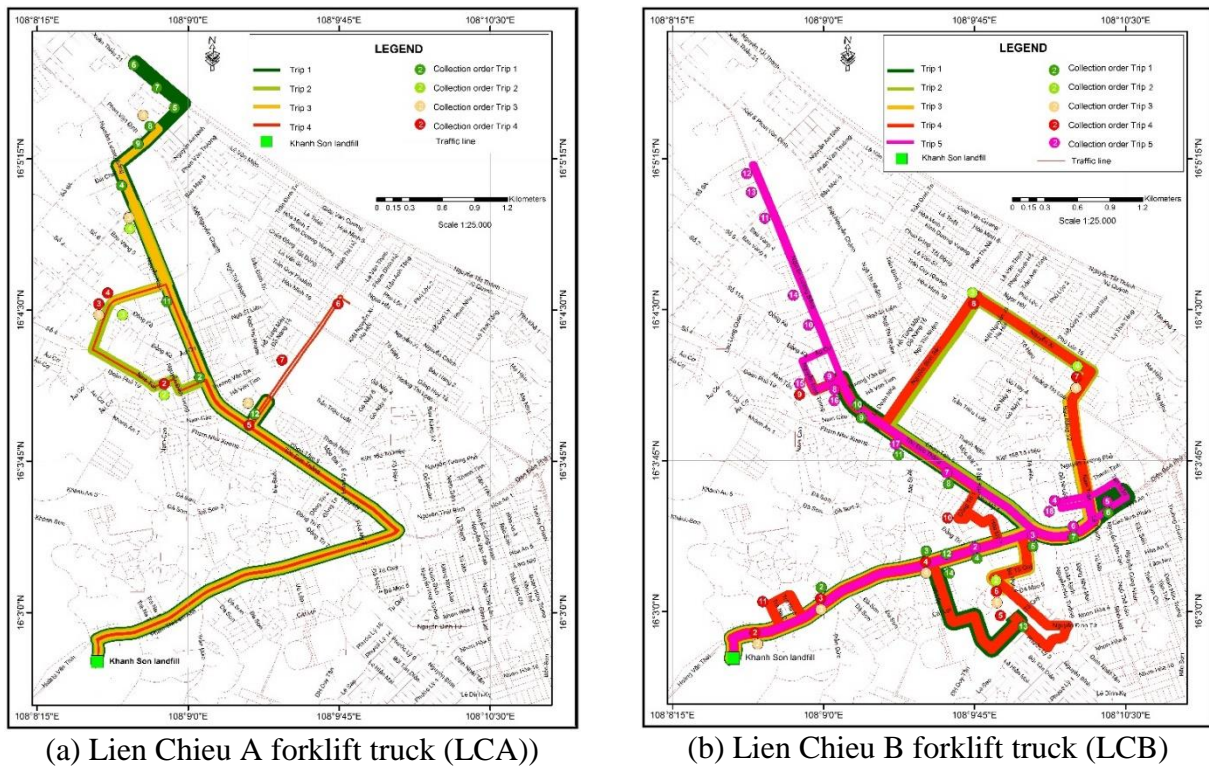
Figure 5. Optimal waste transportation route map of Lien Chieu District, Danang City

Table 1. Information on the optimal waste transportation of forklifts in Lien Chieu District, Danang City

Trip name	Total time (hours)	Starting time	End time	Distance (km)	The volume of garbage (tons)
LCA_1	1.65	6:00	7:39	18.3	11.0
LCA_2	1.28	9:00	10:16	15.6	11.0
LCA_3	1.28	11:00 am	12:16	17.4	11.0
LCA_4	1.42	13:30	14:54	17.2	10.1
Total LCA	**5.62**			**68.5**	**43.1**
LCB_1	2.05	6:00	8:03	16.5	11.0
LCB_2	1.23	9:00	10:14	14.3	10.6
LCB_3	1.28	11:00 am	12:17	11.9	9.7
LCB_4	1.57	13:30	15:03	18.8	11.0
LCB_5	2.32	18:00	20:19	20.4	11.0
Total LCB	**8.45**			**81.8**	**53.4**
Optimal route	**14.07**			**150.4**	**96.5**

It is obvious to see from Table 3 that the optimal waste transportation route can reduce the travel time and distance compared to the current route. Specifically, waste transportation time

is reduced by nearly 40 minutes, traveling distance is reduced by about 14 km and the number of trips is also saver with 1 trip smaller than the current route. This will increase the efficiency of the waste collection process and reduce the environmental pollution due to the saving of distance and travel transportation time.

4. CONCLUSIONS

MSW management is always a difficult problem of any urban area. This study has proposed an optimal waste transportation for forklift trucks in Lien Chieu District, Danang City that can bring the efficiency in time and travel distance. From the results of building and evaluating the efficiency of waste transportation routes using GIS in Lien Chieu District - Da Nang City, it can be concluded that integrating of GIS with the Network Analyst tool brings the high efficiency and quick results. Results from this study can help us to come up with the most reasonable waste transportation option according to the required conditions and the available database source.

5. REFERENCES

Amirhossein M., Putri Md B., Munirah R. Md M., Noordiana K. (2013) Solid waste collection routes optimization via GIS techniques in Ipoh city, Malaysia. Fourth International Symposium on Infrastructure Engineering in Developing Countries; Malaysia.

Amjad K., Mohamed M. S. and Moncef Z. (2016) Using GIS-Based Tools for the Optimization of Solid Waste Collection and Transport: Case Study of Sfax City, Tunisia. Journal of Engineering. Hindawi Publishing Corporation, Volume, Article ID 4596849, doi.org/10.1155/2016/4596849.

Apaydin O. and Gonullu M. T. (2007) Route Optimization for Solid Waste Collection: Trabzon (Turkey) Case Study. Global NEST Journal, 9(1): 6-11.

O'Connor, D. L. (2013) Solid Waste Collection Vehicle Route Optimization for the City of Redlands, California (Master's thesis, University of Redlands). Retrieved from https://inspire.redlands.edu/gis_gradproj/201.

Phatsasi P. and Kampanart P. (2018) Application of GIS for analysis current waste collection routes and find potentiality routes of Thapho sub-District, Mueang Phitsanulok District, Phitsanulok Province. The International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS); Can Tho, Vietnam.

Yadav Sk. (2013) GIS Based approach for site selection in waste management. International Journal of Environmental Engineering and Management; 4: 507-514.

Swapan Das, Bidyut Kr. Bhattacharyya (2015) Optimization of municipal solid waste collection and transportation routes, Waste Management, Volume 43, September 2015, Pages 9-18

The World Bank (2018) Solid and Industrial hazardous waste management assessment: options and action areas, World Bank Publications, 156 pages.