Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 7, Issue 02, February -2020

Route Optimization

Solid Waste Management System by using Geographical Information System (GIS), in Lahore, Pakistan

Engr.Sohaib Ammar Asdaq[1], Dr. Saadia Tabassum[1], Dr.Ammad Hassan Khan[1], Dr.Abdur Rahim[1], Hadeeqa Babar[2]

[1]*Department of Transportation Engineering and Management, University of Engineering and Technology, Lahore*
[2]*College of Earth and Environmental Sciences, University of the Punjab, Lahore*

Abstract—*This report will introduce the use of Geographic Information System (GIS) in the field of Solid Waste Management. The study will demonstrate the aid of GIS through Route Optimizationin different areas of Lahore. It will increase system efficiency, reduce workload, save time and cost.The study also proposes plan for transportation of waste from dustbins to the dumping site through waste municipal trucks via optimised routes such that they cover shortest distance in disposal of waste through efficient paths.*

Keywords- *Solid Waste Management, Route Optimization, Geographic Information System, Optimal Routes, Collection Points, Lahore Waste Management Company*

I. INTRODUCTION

Solid waste management is an issue in high populated areas. Improper solid waste management leads to both economic and environmental sufferings.Roughly 5 million people in Pakistan die due to Waste Management issues. Annual growth rate of about 2.4 percent and 0.65 kg/capita/day is the standard of generation rate for Asian countries and almost 30 million tons of Solid Waste is generated in Pakistan.Collectively solid waste is mainly of different types with variable percentages.

Pakistan being the 6th most populated country in the world and because of lot on consumerism a huge amount of Waste is produced on daily basis. Waste management sector in Pakistan is afflicted by a wide variety of social, cultural, legislative and economic issues. Despite of the presence of certain dumping sites most municipal waste is either burned, disposed or buried on vacant plots due to the negligence of authority and illiteracy of people, this situation is alarming and threatening the health and welfare of the general people. In Pakistan, Negligence in SWMS (Solid Waste Management System) include improper collection of waste, waste accumulation along roads, lack of proper processing of waste and disposal systems and lesser involvement of stakeholders, thus this problem has become one of the major concerns for the authority. This project through GIS and network analysis shows the techniques that can be useful for management of this waste. Geographical Information System (GIS) can provide spatial and non-spatial information for town planning and management. The GIS is being used by the local authorities in the developing countries to collect data, analyses and plan in Solid Waste Management System. GIS helps in analyzing almost all stages of solid waste management that typically includes;Waste Generation, Waste Storage, Collection, Transfer & Transport, Disposal, Treatment Strategies.These stages can be adopted more efficiently with using tools and techniques of GIS, thus helping in improvement of solid waste management system. In this project,numerous transfer stations for collection of solid waste were optimized and efficient routes for disposal of waste from those stations to the main dumping site was computed in order to present more efficient waste management system throughout the concerned area of Lahore thatis “Shalimar Town and Township Area Lahore .”

Solid Waste Management (SWM) has for some time been a dismissed segment in Lahore because of absence of strong commitment with respect to government. City District Government Lahore (CDGL) built up LWMC under area 42 of the Companies Ordinance 1984 on March 19, 2010 be that as it may, this organization is constrained by assurance having no offer capital and is framed not for benefit inside the significance of Section-42 of the Companies Ordinance. There should be more alternatives with technologies need to adopt for better solid waste Management System. The Advance GIS (Geographic Information System) offers great saving in a better way of handling Waste

1.1. Study Areaand Problem Identification

The Study areasare Shalimar Town (Partially), Aziz Bhatti Town (Partially) and Township Lahore.Lahore has a semi-arid dry atmosphere. Lahore Waste Management Company (LWMC) is responsible for proper collection and disposal of solid waste produced but lacks proper solid waste management system, it produces 5500 tons of waste per day which is disposed in open plots and heaps of garbage is piling up in the city. Authority still struggling to manage this waste and dispose them in proper areas. LWMC has already 1 dumping site at Lakhodiar.

Waste Management seeks a solution that will meet three fundamental objectives, which are:
1) Reducing Routes: Cost Saving
2) Balancing the Workload: number of routes across days of the week
3) Adherence to business constraints.
The main purpose of this research on solid waste management by using GIS "Arc Map software" (that acquire, store, manipulate, analyze and present the spatial data), is to;

- Analyze current routes of Dumping Trucks carrying Solid Waste.
- Finding the optimal route to save time and money as well.
- Guide the truck driver to reach their destination, by providing them the direction chart.

Solid waste management incorporates the control of generation, stockpiling, accumulation, movability, transport, preparing and transfer of solid squander. The objective of this study is to exhibit the utilization of geographic information (GIS) in various regions identified with solid waste management so as to expand framework effectiveness, lessen the waste managing task at hand, spare time and cost, to amplify the benefit and serviceability as well as its use as a decision support system.

Figure 1. Lahore City with its Road Networks

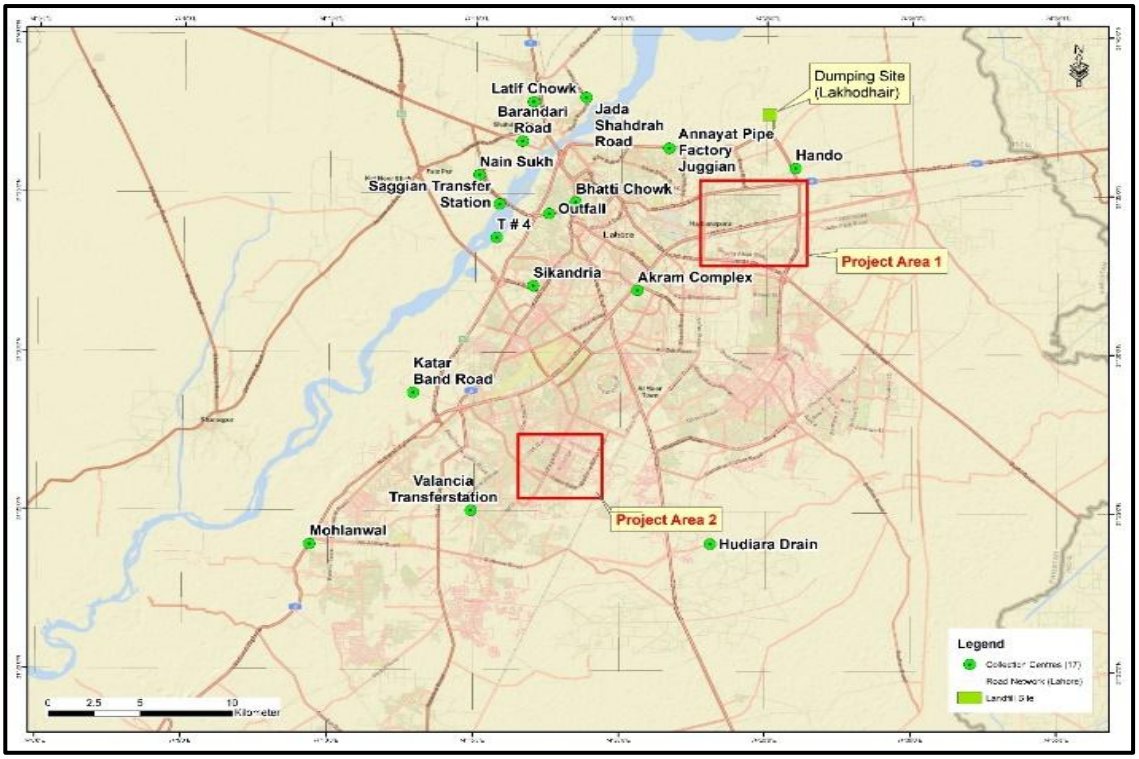


Figure 2.Lahore City (Location of Project Areas and Dumping Site)

II. Design Considerations – GIS

Almost all the solid waste management related factors have a spatial and a non-spatial component. Manual analysis of such factors is a lengthy and tedious process, making it even harder to evaluate them without the assistance of a software program, like an optimization software, making it likely that the spatial and the non-spatial data get merge. The data regarding solid waste, in most cases, lie in isolated form because of improper management. A proper way of management is needed to integrate the data and reduce the complexity of various systems and solve interrelated issues. This makes the geographic information system (GIS) an absolute necessity. GIS helps in dealing with multiple factors simultaneously when waste management planning is considered. Since GIS has a layered property, it minimizes the chance of confusion and error, which enables it to coordinate between the spatial and the non-spatial data. Another advantage of GIS is that the data can be exchanged, compared, evaluated, related spatially and processed with an excellent flexibility.

The issue of waste is not only because of increase quantities but also largely because of inadequate management system (E. Tinmazand I. Demir, 2005).

One of the major management issues in solid waste management is improving methods for interpretation of data , billions spent in improving scientific methods for interpretation of data, but the steps involved in the said area are much demanding (Dr. Vhora, 2006).

GIS is a system designed to allow user to collect, manage, analyze, and retrieve large volume of spatially referenced data and associated attribute data collected from a variety of sources(S. Upasna and M.S. Natwat, 2003).

City has the third largest metropolitan area but somehow improper solid waste management system still exits, although two waste management companies also work here it, that deal with collection and disposal of 2550 tons of totalwaste into dumping site (Lakhodair)generated per day in Lahore, other than 2550 tons of waste, it is disposed in open plots and heaps of garbage is piling up in the city. Authority still fails to manage this waste and dispose them in proper areas.

2.1. Map Spatial Analyst

ArcMap is famous for doing some major analysis like:

- Best site selection by given conditions.
- Find the best route by using Network analysis.
- Find the spatio-temporal changes of any land i.e. may be of soil, vegetation etc.

2.2. Routing

Routing the process in which we find the best and suitable track to reach our destination; That leads to these advantages**; save time, reduce distances, save money.**

III. METHODOLOGY

The **functional elements** of solid waste management are the following:

- Generation of Solid Waste.
- Handling, Separation, Processing, and Waste Storage at the source
- Collection & Transfer/Transport of Waste.
- Separation, Processing, and Transformation of Waste.
- Disposal through GIS Application in SWM

The **methodology of study**includes:

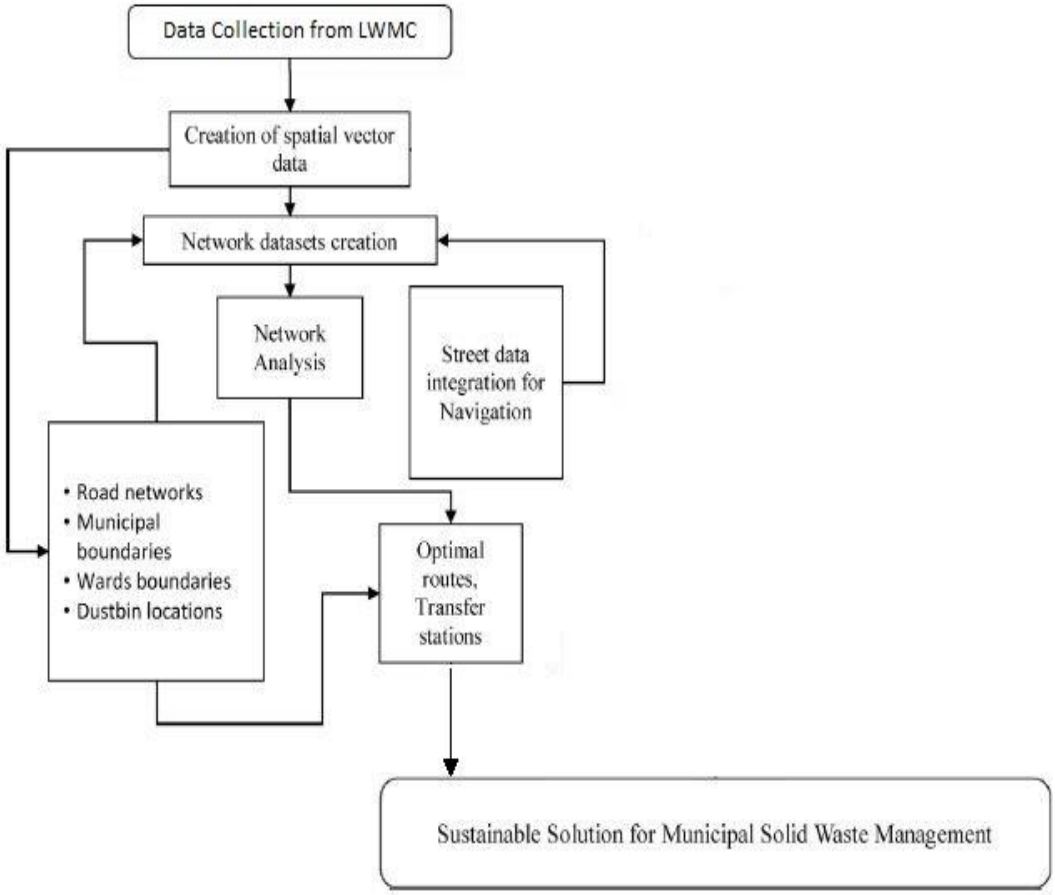
1. Collectionof data regarding waste disposal situation in **Lahore City**. City information is available in four different mediums which will be brought together in one plat form where they can be linked together and correlated. These four mediums are: - Maps containing spatial information. - Spatial data about location of waste bins and buildings. - Attribute information about spatial data. - Other information source through interview with municipal officials to provide information about working patterns.

2. Preparing a database about the waste situation.

3. Analysis of present situation, to recognize problems as well as limitations and restrictions in city waste management.

4. Discussion and critical analysis of SWM models presented in literature studies.

5. Design and implementation of conceptual GIS model, and problem analysis using GIS Application in SWM.



3.1. Data Collection and Limitation

As stated previously, data was collected through four different mediums, maps, spatial data about locations, attribute information about spatial data and other information through survey, interview, and questionnaire. Then all information from different types and forms transferred to the GIS database. Information about shops and their locations was collected and they were categorized according to the waste generated in the shops, for this purpose the waste generated by shops was divided into three categories which are composite (organic), recyclable (inorganic), and mixed waste.

3.2. Criteria for Selection

3.2.1. Objectives

—Minimize the number of vehicles,

—Minimize travel time,

—Balance workload among the vehicles.

3.2.2. Constraints

—Time windows of stops and the depot,

—Vehicle capacity (volume, weight),

—Route capacity (maximum number of homes (residential) or lifts (commercial), a vehicle can handle per day),

—Routing time limit per vehicle,

—Disposal trips (when a vehicle is full, it must go to a disposal facility)

The dataof OSM in Global Mapper has been used. The data is first downloaded, Imported and finally exported to ".shp" format. Subsequently the dummy data of dustbins has been prepared for collection of waste. Then the zones of study area have been made based on Trucks availability so that it would cover dustbins according to their availability. And afterwards junction and routing data has been generated from Arc Map Network Analyst and based on this the analysis has been performed.

3.3. Data Analysis

After deciding the datasets and acquiring these from various sources (internet, published data & digital data), the analysis of these data for checking of errors was carried out. To explore the datasets, it required an understanding of which attribute within and between the datasets is important for solving the problem.

- Calculate the number of Dustbins
- Calculate the distance from each dust bin to collection point.
- Calculate the distance from the landfills.

3.4. Data Processing

We download the data from Open street maps which is in the form of xml file. So, we import our Data in QGIS where we convert our file to shapefile to get all the data for ArcMap.

3.5. Importing Data in Arc Map

Data is added from the directory by using add data option.

3.6. Locations of Dustbins

The points of dustbins are imported from the point coordinates files received from LWMC. Few steps are as under.

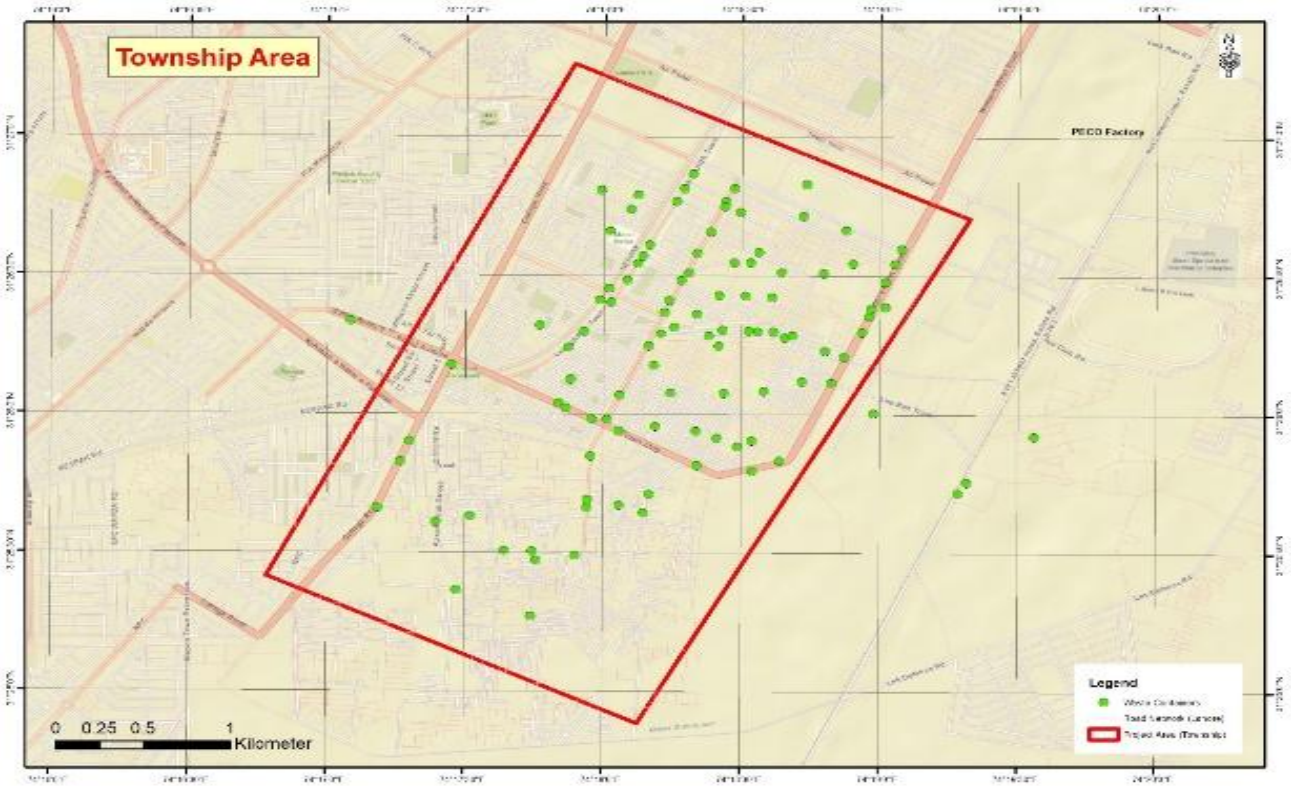


Figure 3. Location of dustbins in study area 1 (Township)

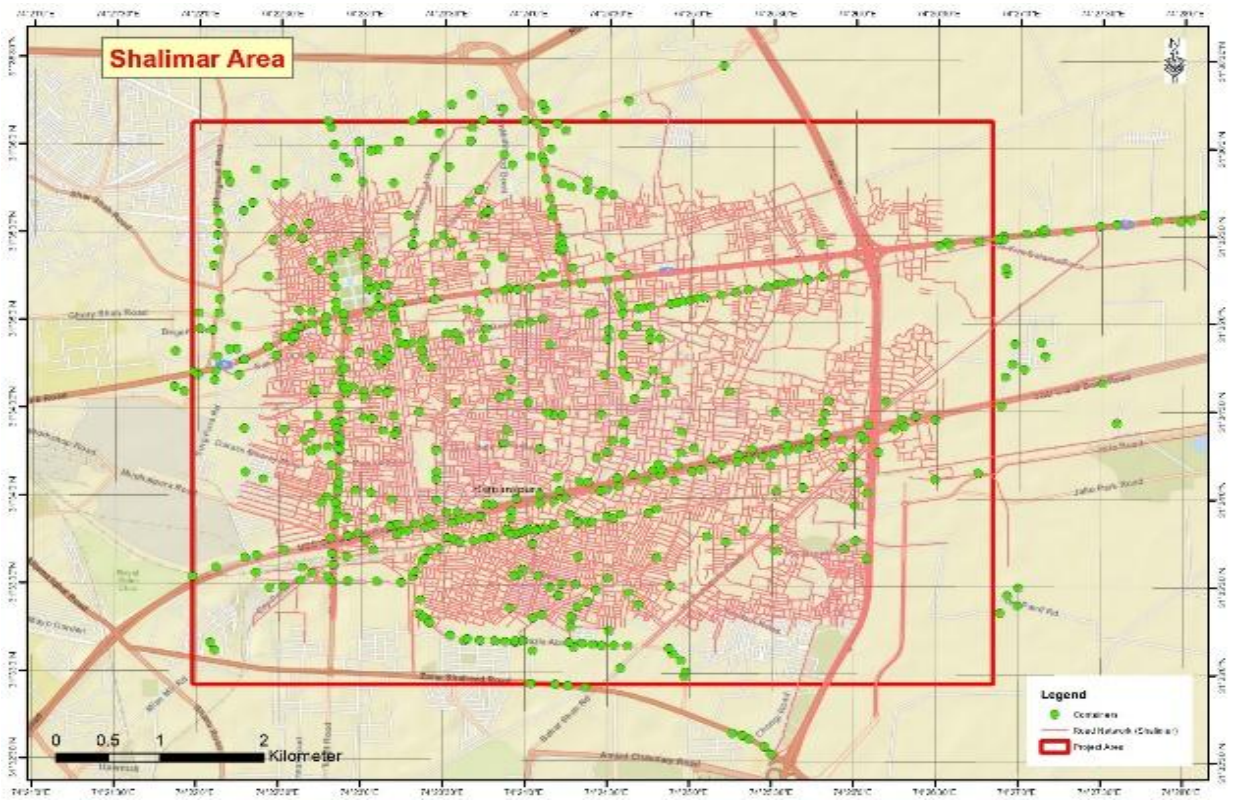


Figure 4. Location of dustbins in study area 2 (Shalimar Town)

IV. RESULTS& DISCUSSION

4.1. Optimal Routes:

Municipal Cooperation is area from where truck departs for collection of waste and dump it to their respective dumpsites, optimal routes for this purpose were calculated using **Network Analysis in ArcMap**. Overall optimal routes and the optimal routes for each zone has been shown below. It represents the shortest and most efficient path available for the trucks to depart from the municipal cooperation cover their assigned zone and dump it to the dumpsite.

Network Analysis tools were used to calculate these optimal routes in order to save time, reduce distances and save money. For this study a spatial vector data was created for the roads and is being used. Route Optimization is performed on two areas of Lahore (Shalimar Town and Township). Locations and Coordinates of dust bins was collected from Lahore Waste Management Company+. As a result of this there is significant reduction in travel time of dump trucks to collect solid waste, also there is increase in coverage of multiple dustbins. The detaildiscussion along with the map's areas under.

Figure 5. Unoptimized Route of Shalimar Town

The map in Figure 5, are unoptimized routes that were followed by the Trucks to collect solid waste from dust bins placed in the area of Shalimar Town. As can be seen that the accessibility to most of the dustbins is not possible because of the width of roads/streets. For that purpose, most of the dustbins were left neglected and the waste there was removed after a long span.

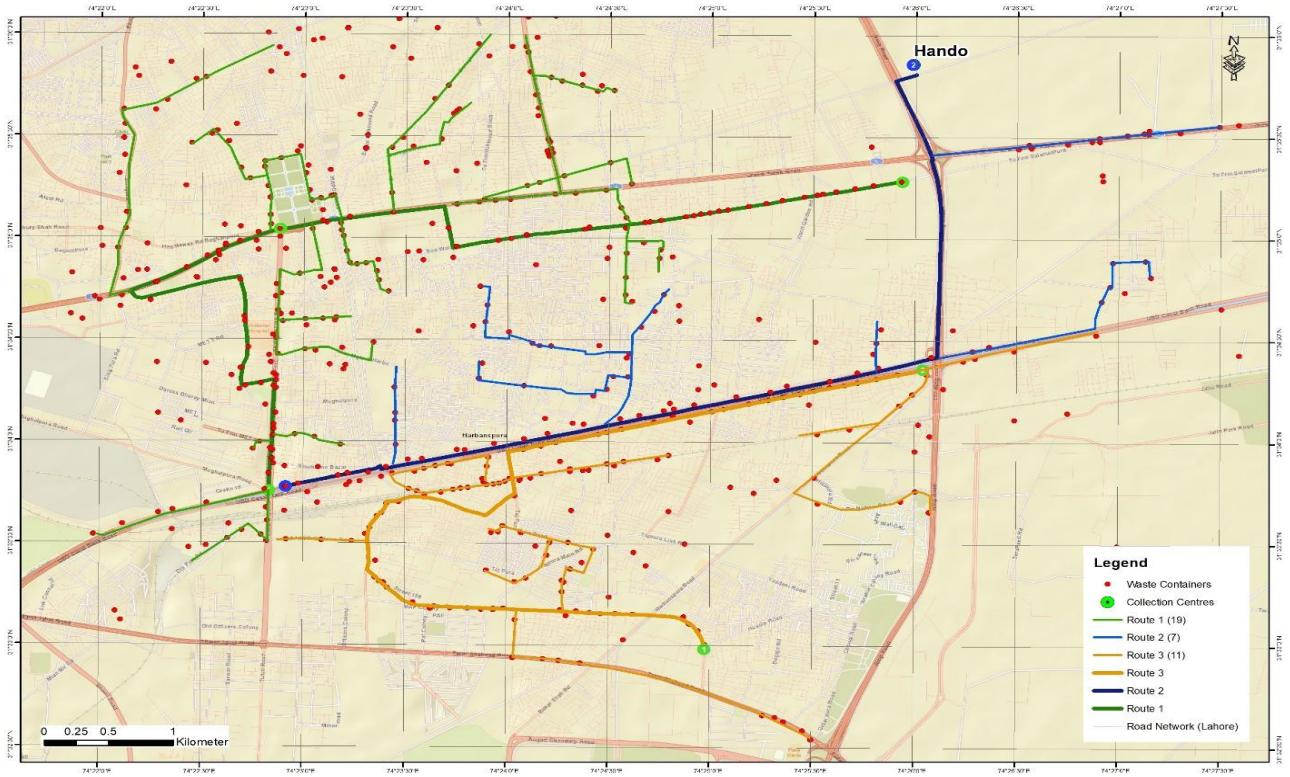


Figure 6. Optimized Routes (With Sub Routes Zone Wise)

This map in Figure 6, depicts the Detailed Route Plan of the Project Area-1, with the coverage of maximum possible containers in the area. However, the position of some containers needs to be replaced so that the distribution of containers all in the city is maintained and maximum waste can be transported to their respective Dumping Sites. Different detailed routes have been proposed for this Project Area with their starting locations at different places, but the ending station Hando is constant for all the routes. Minor routes are also generated to ease the drivers about the location of dust bins. It is to be noted that a dump trucks won't be able to access the road/streets along the minor routes. For that small dumpers will be needed. Based on the data gathered from LWMC it will be easy for them to collect the solid waste from those routes as well because they have numbers of small dumpers.

Table 1. Shalimar Project Area Comparison Table

Shalimar Project Area						
		Unoptimized Routes		**Optimized Routes**		
		Major Route (1)	**Minor Routes (0)**	**Major Routes (3)**	**Minor Routes (37)**	
Sr. No	Factors	Units	-	Units	Units	
1	Length	20.75 km	-	25.8 km	37.2 km	
2	Coverage	34.00%		25.50%	45.30%	
	Total Bins	**637**	**Bins Coverage of Unoptimized Route**	**216**	**Bins Coverage of Optimized Route**	**451**

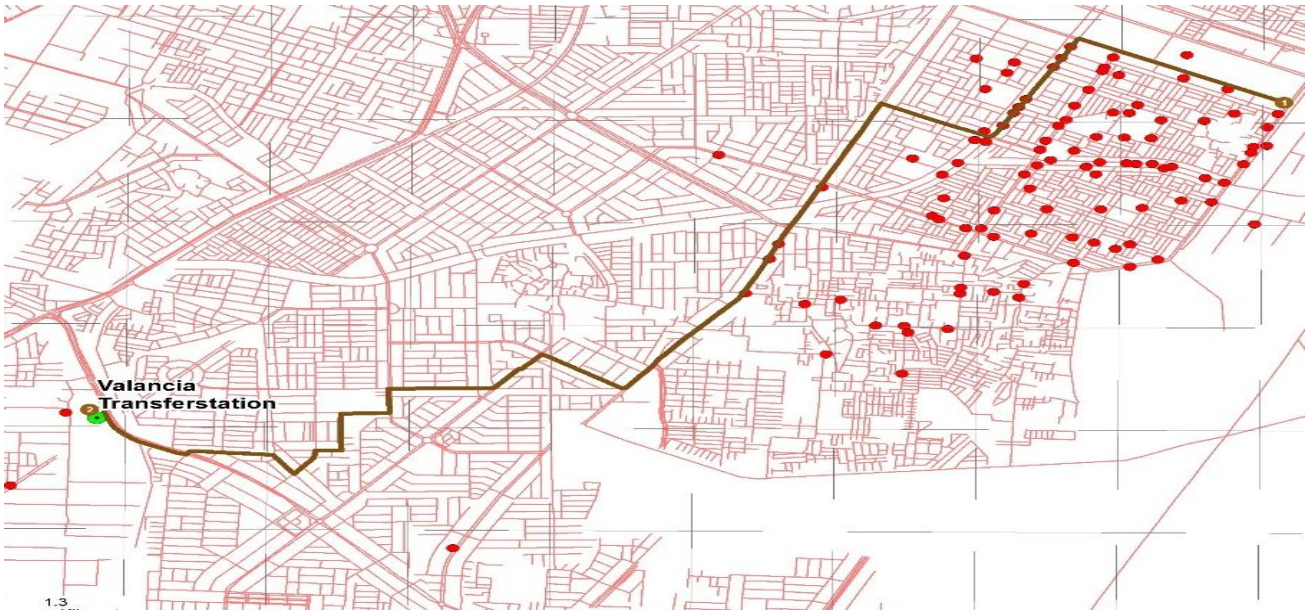


Figure 7. Un Optimized Route Township

The map in Figures 7, illustrates the Route Plan for Project Area-2, however this route is only passing through the primary roads and covering all the containers on the on it and ending at the Valencia Transfer station dumping all the collected waste from the containers. The major area coverage of this route is Township and Model Bazar where transportation of waste is very necessary. However, this is not the optimum route because all the containers are not being encountered in this scenario which is the major objective of this Route Planning.

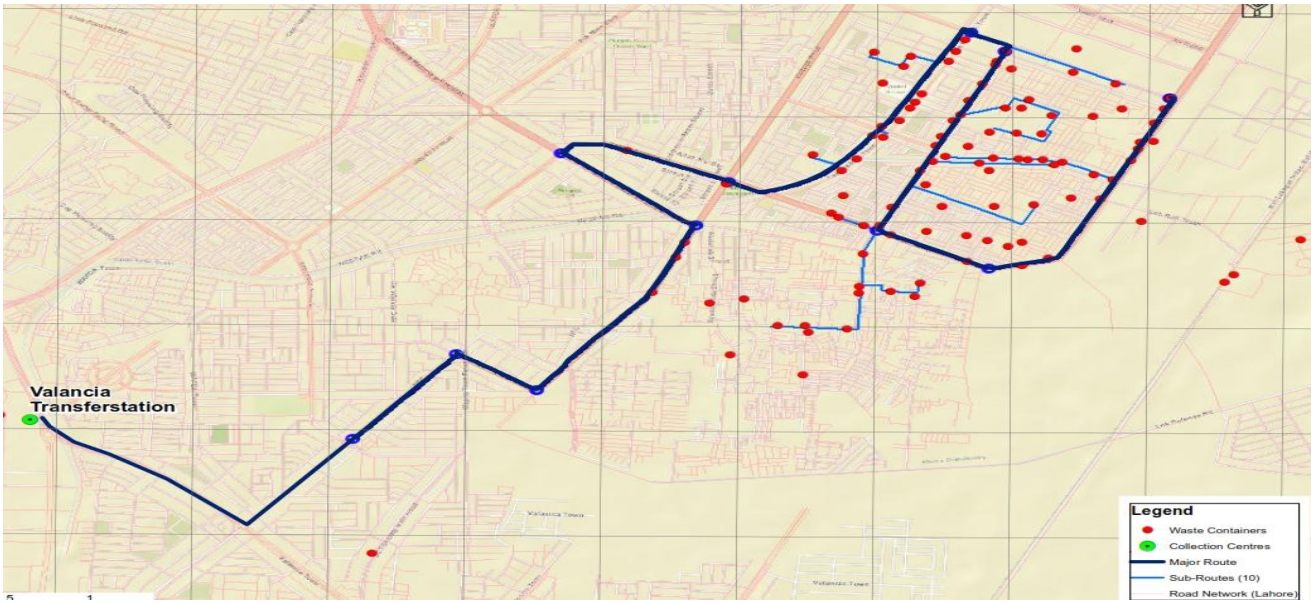


Figure 3. Optimized Route with Sub Routes

The maps in Figure 8, is the detailed route plans of the Project Area- 2, covering almost all the containers placed by LWMC for the collection of waste. All the Containers in the Township and Model Bazar are covered in this Route. However, the positions of some containers need to be changed, to make it appropriate for the coverage of route in one go without any delay of time and the consumption of fuel. This optimum Route Plan for Township and Model Bazar will not only save time but also is shortest route that will result in lesser fuel consumption, which is the Major objective of this Route Analysis. Minor routes area also generated here with the help of software to ease the drivers to get through majority of dust bins.

Table 2. Township Project Area Comparison Table

Township Project Area						
		Unoptimized Routes		**Optimized Routes**		
		Major Route (1)	**Minor Routes (0)**	**Major Route (1)**	**Minor Routes (10)**	
Sr. No	Factors	Units	-	Units	Units	
1	Length	10 km	-	14.9 km	8.4 km	
2	Coverage	14%		41.10%	41.10%	
	Total Bins	**101**	**Bins Coverage of Unoptimized Route**	**14**	**Bins Coverage of Optimized Route**	**83**

From the collection centre routing is done that facilitates municipal team members by providing them proper directions at every turn from their origin to destination. This will help them perform their task of collecting waste and disposing it to dumpsite even more efficiently.

V. CONCLUSIONS

This paper begins by giving brief presentation about solid waste (SW) and Solid Waste Management (SWM). It refers to the advantages of geographic information system (GIS) in Route Optimization. Three useful components of SWM were examined, which are waste capacity, waste accumulation, and waste transfer. It likewise gives route subtleties to the trash gathering groups (Municipal Authorities) that can be utilized for gathering the loss from the exchange stations more efficiently.

- The research will enable to make waste collection arrangements in a manner to get the best outcome.
- GIS for route optimization in Lahore city has demonstrated sensible improvement in length of the routes and travel time minimization.
- The detailed routes were found to be most cost efficient. The bins that are not being able to cover in the detail route map are those routes where the road width is not optimal for the waste collection truck to move.
- This study also infers that there is a need to propose new locations for some waste bins, so that they may also be covered in the same route.
- Route Optimization to existing frameworks helps to create information and propelled strategies to plan and assess new frameworks for urban zones.
- Detailed Route Maps depicts that the coverage of bins for waste collection. In other words, the detailed route was the most efficient route with respective to our variables time and fuel.

VI. RECOMMENDATIONS

- This project can also be used as foundation for future working to focus on the optimal site selection for the waste bins. This research is very sensitive one of its kind. It has been called sensitive just because in order to make this route optimal, some factors like traffic, time spent from one bin to next bin for the collection of waste, travel speed of the truck etc.
- The outcomes acquired from this pilot study are urging to extend the scope to cover whole city for streamlining of the courses for solid waste collection. This will diminish the dependence of city committees to transfer destinations and increase disposal sites operational life.

VII. REFERENCES

[1] Ammir. Y , July’27 2017, Pindi citizens suffer as CDA dumps garbage along IJP Road, Dawn News.'
[2] Bhat, V. N. (1996). A model for the optimal allocation of trucks for solid waste management. *Waste Management & Research*, *14*(1), 87-96.
[3] Chang, N. B., Lu, H. Y., & Wei, Y. L. (1997). GIS technology for vehicle routing and scheduling in solid waste collection systems. *Journal of environmental engineering*, *123*(9), 901-910.
[4] Das, S., & Bhattacharyya, B. K. (2015). Optimization of municipal solid waste collection and transportation routes. *Waste Management*, *43*, 9-18. Das, S., & Bhattacharyya, B. K. (2015).
[5] Ghose, M. K., Dikshit, A. K., & Sharma, S. K. (2006). A GIS based transportation model for solid waste disposal–A case study on Asansol municipality. *Waste management*, *26*(11), 1287-1293.

[6] Huang, B., Cheu, R. L., & Liew, Y. S. (2004). GIS and genetic algorithms for HAZMAT route planning with security considerations. *International Journal of Geographical Information Science*, *18*(8), 769-787.
[7] Jinan Li, Steven Lane, Tom McMurtrie, 1996, *the Sixteenth Annual ESRI User Conference*, Palm Springs, California, May 20-24, 1996
[8] Jaydeep.L, Venkata.R, Xuan.Z(2017),Solid waste collection/transport optimization and vegetation land cover estimation using Geographic Information System (GIS). *Sustainable Cities and Society*,Vol. 35, Pages 336-349.
[9] Lahore Waste Management Company Data (2019).
[10] Michelle M. Groce, 2002, Routes, Requests, Bids, and Citations: *GIS in Solid Waste Services, the Twenty-Second Annual ESRI User Conference*, San Diego, California, July 8 – 12, 2002.
[11] Optimization of municipal solid waste collection and transportation routes. *Waste Management*, *43*, 9-18.
[12] The Ozpak Report (2019).
[13] Virginia GIS reference book, www.geodecisions.com, accessed on Oct 05, 2019.
[14] Wikipedia (2018), Lahore. Retrieved from; https://en.wikipedia.org/wiki/Lahore, accessed on Oct 10, 2019.

