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Route Optimization of Municipal Solid Waste Collection in Jabalpur City using ARC GIS

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ABSTRACT

Uncontrolled growth of the urban population in developing countries in recent years has made solid waste management an important issue, so the system for collection of solid waste thus constitutes an important component of an effective solid waste management system. Waste collection become more complex in developed countries in terms of logistic, fuel , labor cost and air pollutants emission. In this study, solid waste collection routes optimization using Geographical Information System (GIS Arc View) was investigated. The present routes were optimized to reduce the length of the routes and consequently the time taken to complete the collection. The problem of waste collection in Jabalpur city has been considered where sources are dispersed by varied way. In this work, the waste transportation problem for time and cost effective waste management system design has been carried out. The work proposed a route upgrading associated with the current routes taken by the solid waste collection trucks in the Rampur area (Jabalpur); and shows a better performance in terms of fuel consumption, emissions from the trucks and less operational costs, making it a solution to urban environmental management.

Keywords: *Municipal solid waste management, waste collection, Route Optimization, Urban Area, Arc GIS software, Geographical Information System (GIS)*

1. Introduction

Solid waste generated by the daily activities of the people needs to be properly managed in such a way that it minimizes the risk to the environment and human health. Inadequate collection and disposal of solid waste is a major factor in the spread of disease and environmental degradation. One of the most visible problems in the provision of solid waste management (SWM) is the collection route developed and save the cost of fuel and time of service of the solid waste, which is the subject of this paper. Solid waste management is undoubtedly an increasingly important element in terms of efficiency and profitability for any municipality .The routing optimization problem in waste management has been already explored with a number of algorithms. Moreover, the successful implementation of vehicle routing software has been aided by the exponential growth in computing power since 1950, the emergence of accurate and sophisticated Geographic Information Systems (GIS) technology induced multiple algorithmic solutions.

Solid waste management today is made difficult and costly by the increasing volumes of waste produced, the need to control what are now recognized as potential serious environmental and health effects of disposal, the lack of land in urban areas for disposal purposes, partly due to public opposition to proposed sites. Waste management, once strictly a local and private sector matter, now involves regional, state and federal authorities. Various legislative initiatives and procedures have been activated within the last few years in the leading industrial countries.' The two primary reasons to have solid waste management on a regional instead of on the level of local towns and cities, which is the current practice, are economical and technical and political feasibility.

2. Study Area

Jabalpur lies on the banks of the Narmada River and sprawls over the plains of its tributaries Hiran, Gaur, Ken & Sone. Geographically, the city is located at 23°10' North latitude and 79°57' East longitude, at an altitude of 393 meters above mean sea level. The topography of Jabalpur is unique.The territorial jurisdiction of the municipal corporation spans 106.19 sq. km.The current (2011) population of Jabalpur is 1.82 million (2017). The city has experienced relatively moderate growth rates in population during the last two decades- 1981-91 & 1991-2001.The population density of Jabalpur is 478 persons per square kilometer. The district is divided in 13 zones and 79 wards.

In this research work, a Giriraj Kishore ward was chosen as the case study area which comes under zone three that is Rampur zone. The ward no is 11 the population of the ward is 16,349 and the number of households in this ward is 2,629 as per 2011 census. This paper describes a study of planning vehicle route optimization for the waste collection in the Giriraj kishore ward using Arc GIS Network Analyst tool - a user friendly extension of ArcGIS, which provides efficient routing solutions in a simple and straight forward manner.

3. Methodology

3.1. General

In this work we focuses on the collection, transfer and transportation of solid waste from any waste generation sources (households, markets, institutions and offices) to the processing plant or landfill site. The factor influencing the municipal solid waste collection and transportation are:

i. Quantity of municipal solid waste generation;
ii. Number of waste collectors and their deployment to cover the whole city;
iii. Vehicles to run to and from various transfer stations where garbage is gathered to the respective processing plant.

In this work a scheme is proposed for optimizing municipal solid waste collection and transportation routes using the Travelling Salesman Problem (TSP). The proposed scheme designs an optimized municipal solid waste management (MSWM) system with respect to transportation route length. The TSP is one of the most prominent problems in combinatorial optimization, and at the same time a quintessential applied spatial analytic challenge.

The proposed scheme divides whole integrated waste management system into four different parts (shown in Fig. 3.1).

i. Collection of segregated solid waste from various sources (households, markets, offices and institutes) and conveyed waste to the nearest collection centre;
ii. transfer accumulate solid waste from collection centre to the adjoining transfer station;
iii. transport the segregated solid waste from the transfer station to nearby categorized waste processing plant;
iv. transfer the produced waste from processing plant to the nearest landfill site.

Each part contents huge amount of cost for waste collection or waste material transportation. The proposed scheme optimizes transportation cost of each part of the system. Therefore, the total waste management cost for the whole system is optimized.

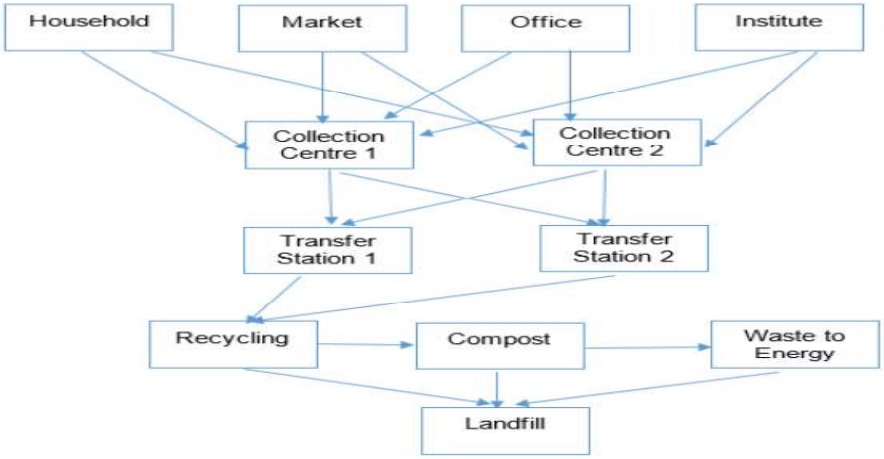

Figure 3.1.: Architectural view for MSW collection and transportation

3.2. GIS model application

The Global Positioning System (GPS) technology was used to collect data on dumpsites and routes. A Magellan® Triton 1500 model GPS was used in collecting and storing data that was later integrated into and managed by GIS software.

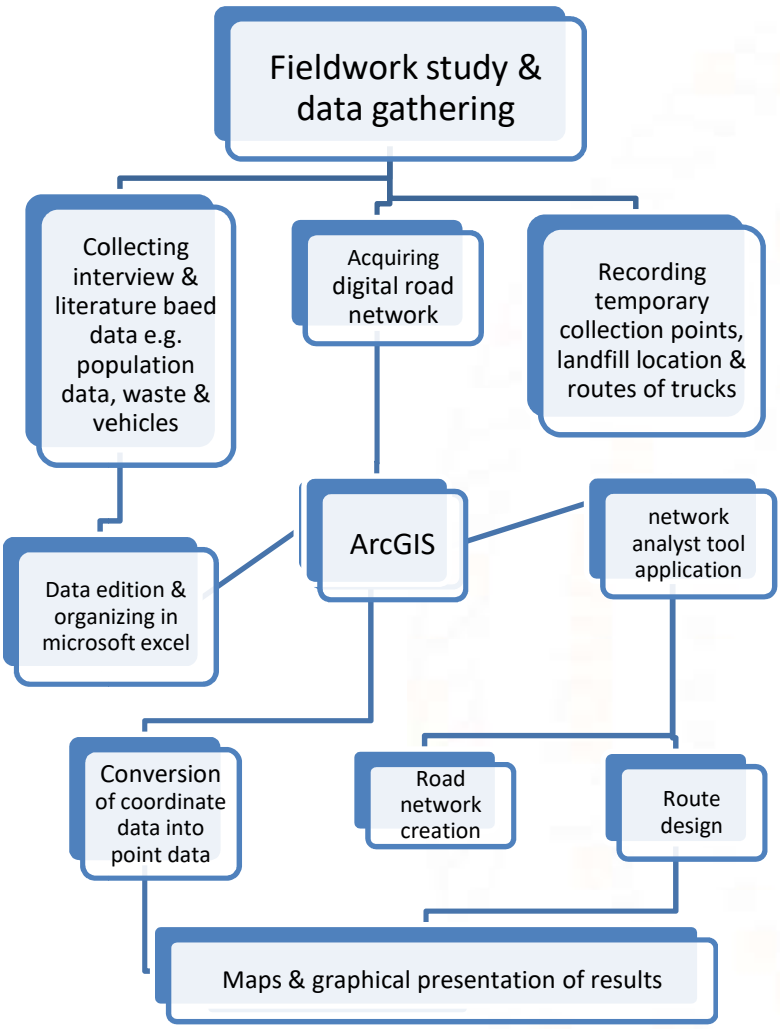

Figure.3.2. GIS methodological structure

With the GIS application through the Network Analyst extension, an optimization module was developed to calculate the shortest distances. The GIS software took into account parameters in solid waste management such as location of dumpsites, truck capacities, the road network as well as the waste generation volumes of the area. The structure of the methodology that was followed is shown in Fig. 3.2.

3.3. Phases of the proposed methodology

Fig.3.3 shows a schematic representation of the phases of the methodology proposed. The first phase of the methodology consists of number of sources, which are scattered throughout the area under consideration by heterogeneous way. Each of the source is connected to its neighbour sources by at least one route or more than one route.

In the first phase, we have pointed out all sources and all possible connecting routes between them according to existing map. Then we apply our proposed route optimization technique to find out the optimal routes for waste collection.

In the second phase, our main objective is to transport waste from collection centres to transfer stations through optimal routes. Therefore, the location of the collection centres and routes have been selected according to the existing map. Then we apply our proposed scheme for second phase optimization.

In the third phase, the location of the transfer stations and routes between them has been identified through the detail existing map study. Then we found out the optimal route between the transfer stations by applying our third phase optimization process. The combination of these three phase output shows the optimal way of waste collection, transfer and transportation.

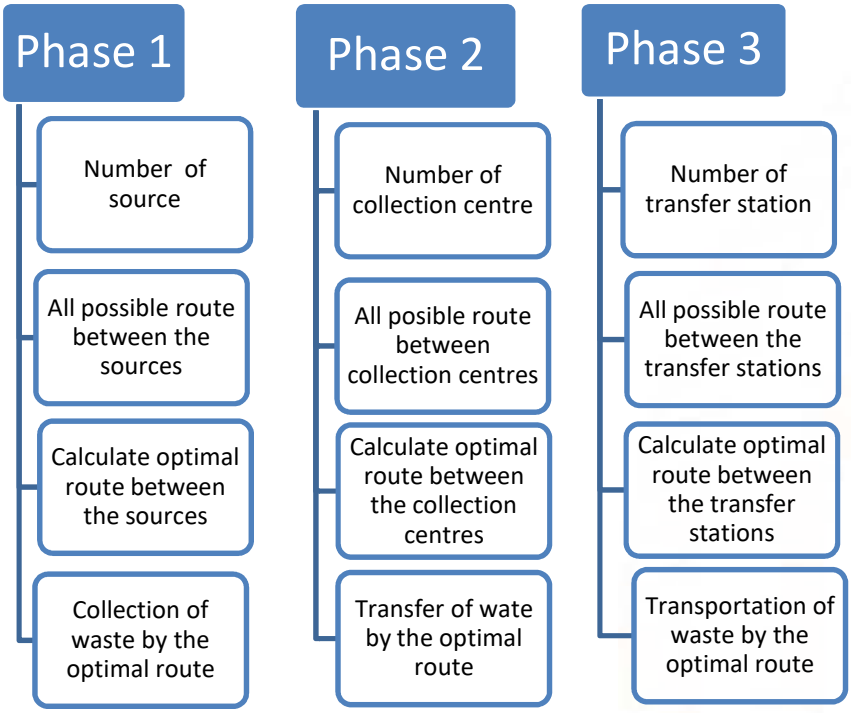

Figure.3.3. Schematic representation of the phases of the methodology proposed

4. Result and discussion

4.1. Distance between collection points

One route were defined with the characteristics given in Table .Any reduction of distance between the collection points could be attractive as it reduces the collection time, cost and air pollution emission. There were more than one alternative to estimate the distance between two points. One efficient way of estimation is application of Euclidean space which is made with the Pythagoras theorem.

Table 4.1 Graphic design and length of the routes

Area	Present Length (m)	Optimized length (m)
Giriraj kishore ward no 11	**6435**	**5606**

Total 26 stops were considered in the optimized route plan. In choosing the optimized routes the resources used for the collection i.e. equipment and labour requirement were considered. As the other vital factor, the length of the route and time taken to complete the collection were considered. Figure 4.1 shows the ward map considered for the study. Route plan of ward no 11 has a distance of 6435 m which is optimized up to 5606 m showing the reduction of 12.9%.

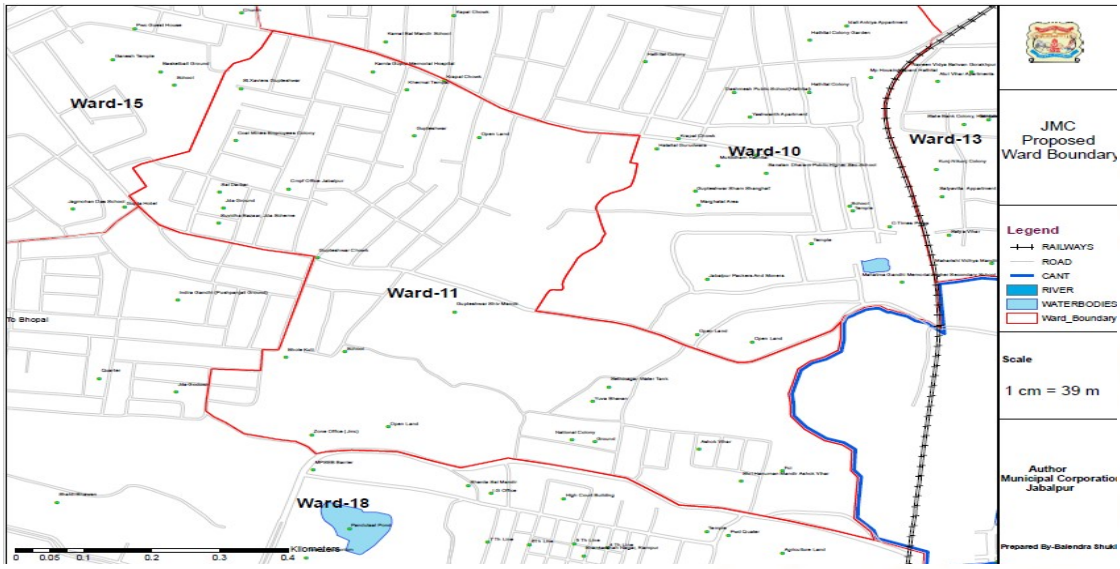

Figure .4.1. Ward Map considered for the study.

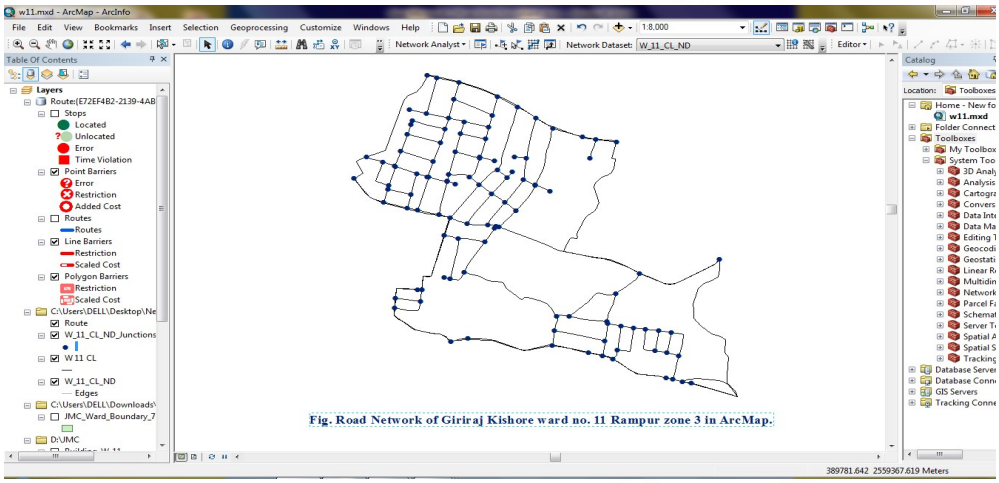

Figure.4.2. Road Network of Giriraj Kishore Ward no. 11 (Rampur Zone 3)

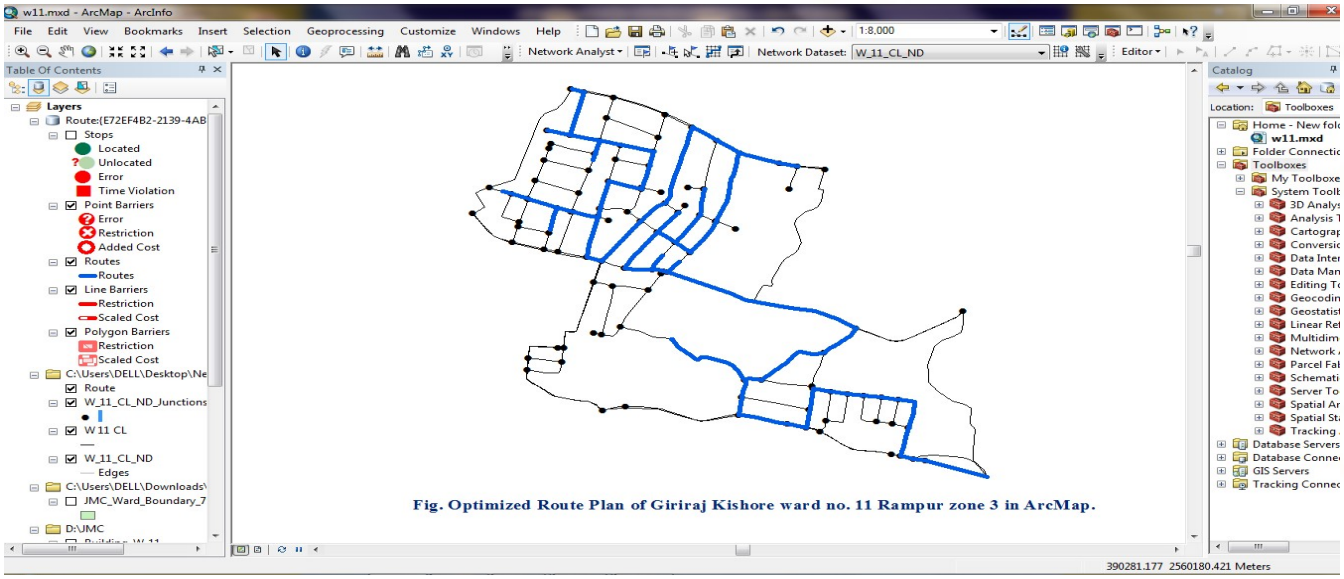

Figure.4.3. Optimized Route Plan for Giriraj Kishore Ward no. 11 (Rampur Zone 3)

Table 4.2 GIS-based designed routes information

Area	Length (m)	Duration (s)	Number of stops	Stops length (s)	Total collection time (s)
Giriraj kishore ward no 11	**5606**	**673**	**26**	**780**	**1453**

(Truck speed and stop duration for each point were assumed to be 30 km/h and 30 s, respectively)

The proper frequency for the most satisfactory and economical service is governed by the amount of solid waste must be collected and by climate, cost, and public requests. For the optimized Route Ward number 11 and based on the measurement distance travelled for the truck (5606 m), the time taken for the solid waste collection was found to be 673 seconds. 26 stops have been designed in the route which resulted in 1453 seconds total collection time in the optimized route plan.

The results shows that the total length reduced from existing routes to the new optimized route is about the 829m per day. This indicates the improvement of collection time in the new design compared to compared situation due to which the operational cost was also reduced. The total length of 100seconds was saved in new route design as the collection duration was reduced.

5. Conclusion

The present study attempts to optimize the routes for transport of solid waste from the Giriraj Kishore ward under Rampur zone in Jabalpur city integrating GIS application ArcView along with GPS tools to track the various routes. It demonstrates the effectiveness of GIS/GPS technology in optimizing the waste transport routes to achieve time and distance savings eventually resulting in a most economic transport model. Further in this Research work, waste collection and transportation problem considered which is arising when planning an effective waste management system. The problem of waste collection in Jabalpur city has been considered where sources are dispersed by varied way. In this work, the waste transportation problem for time and cost effective waste management system design has been carried out.

The work proposed a route upgrading associated to the current routes taken by the solid waste collection trucks in Rampur area (Jabalpur); and shows a better performance in terms of fuel consumption, emissions from the trucks and less operational costs, making it a solution to urban environmental management. In order to further improve on the vehicle operation, vehicle capacity should be increased in volume so as to increase on the utilization, gather more waste at temporary collection points and reduce on time and distance to travel. The Jabalpur city will be able to refer to this research work when implementing a GIS for route optimization in collecting and transporting solid waste. The GIS based routing procedure is flexible and could be used in planning of waste collection policies and decision making mechanisms in waste management. Collection of unseparated and separated solid waste in an urban area is complex as waste generation become more diffuse. Of the total amount of money spent for collection, transportation and disposal of solid waste, approximately 50 to 70 percent is spent on the collection phase. This fact is important as small percentage improvement in the collection operation can effect a significant saving in the overall cost.

Therefore, interest in the analysis of solid waste collection systems arises to optimize the operation of existing systems and to develop data and advanced techniques to design and evaluate new systems for considered areas. GIS-ArcView application for route optimization in Jabalpur city has shown reasonable improvement in length of the routes and travel time minimization. The results obtained from this pilot study are encouraging to expand the scope to cover entire city for optimization of the routes for solid waste collection. In addition to cost deduction, as more and more communities are moving toward mandatory recycling of materials, the route optimization will provide opportunities for separate collection of recyclable waste using same logistic and equipment. This will reduce the reliance of city councils to disposal sites and increase disposal sites operational life.

REFERENCES

1. Angelina Vitorino de Souza Melaré , Sahudy Montenegro González, Katti Faceli, Vitor Casadei,2016, “Technologies and decision support

systems to aid solid-waste management: a systematic review", http://dx.doi.org/10.1016/j.wasman.2016.10.045 .

2. Asase, M., Yanful, E.K., Mensah, M., Stanford, J., Amponsah, S., 2009. "Comparison of municipal solid waste management systems in Canada and Ghana: a case study of the cities of London",Ontario, and Kumasi, Ghana. Waste Management. 29, 2779-2786.
3. Ali Mirdar Harijani, Saeed Mansour, Behrooz Karimi, Chi-Guhn Lee, 2017, "Multi-period sustainable and integrated recycling network for municipal solid waste – A case study in Tehran", Journal of Cleaner Production (2017), doi: 10.1016/j.jclepro.2017.03.030.
4. C.K.M. Lee, C.L. Yeung, Z.R. Xiong, S.H. Chung, 2016, "A mathematical model for municipal solid waste management – A case study in Hong Kong", http://dx.doi.org/10.1016/j.wasman. 2016. 06. 017.
5. Christian Riuji Lohri,Ephraim Joseph Camenzind,Christian Zurbrügg,2014,"Financialsustainability in municipal solid waste management–Costs and revenues in Bahir Dar,Ethiopia" Waste Management 34 (2014) 542–552.
6. Davide Anghinolfi , Massimo Paolucci , Michela Robba , Angela Celeste Taramasso, 2013, "A dynamic optimization model for solid waste recycling", http://dx.doi.org/10.1016/j.wasman. 2012. 10.006.
7. Guo, P., Huang, G.H., 2009. Inexact fuzzy-stochastic mixed-integer programming approach for longterm planning of waste management– Part A: Methodology. Journal of Environmental Management.91, 461-470.
8. Gianpaolo Ghiani, Andrea Manni, Emanuele Manni , Massimiliano Toraldo, 2014, "The impact of an efficient collection sites location on the zoning phase in municipal solid waste management",http://dx.doi.org/10.1016/j.wasman. 2014.05.026.
9. H. W. Gottinger 1985. A computational model for solid waste management with applications. Appl.Math. Modelling, 1986, Vol. 10, October.
10. Hoornweg, D., Bhada-Tata, P., 2012. What a Waste: A Global Review of Solid Waste Management.Urban development and local government unit, The World Bank, Washington, DC.
11. go.worldbank.org/BCQEP0TMO0 (accessed 12.10.16).
12. H.A. Eiselt & Vladimir Marianov, 2014, "Location Modeling for Municipal Solid Waste Facilities",http://dx.doi.org/10.1016/j.cor.2014.05. 003.
13. **Basavaraj N Itnal1, S M Prakash2**. "ROUTE OPTIMIZATION OF COMMUNITY SOLID WASTE MANAGEMENT IN SELECTED WARDS OF BANGALORE CITY USING GEOLOGICAL INFORMATION SYSTEM (GIS)" ,http://esatjournals.net/ijret/2015v04/i11/IJRET20 150411040.pdf.
14. Kanat, G., 2010. Municipal solid waste management in Istanbul. Waste Management. 30, 1737-1745.
15. Katja Buhrkal, Allan Larsen, Stefan Ropke, (2012), "The waste collection vehicle routing problem with time windows in a city logistics context", Procedia - Social and Behavioural Sciences 39 (2012)241 – 254 1877-0428 7th International Conference on City Logistics doi: 10.1016 / j.sbspro. 2012.03.105, the Seventh International Conference on City Logistic.
16. Mizpah Asase, Ernest K. Yanful, Moses Mensah, Jay Stanford, Samuel Amponsah, 2009,
17. "Comparison of municipal solid waste management systems in Canada and Ghana: A case study of the cities of London, Ontario, and Kumasi, Ghana".
18. McDougall, F., White, P., Franke, M., Hindle, P., 2001. Integrated Waste Management: A Life Cycle Inventory, second ed. Blackwell Science, Oxford, UK, ISBN: 0 632 05889 7 (03/11208).
19. Ola M. Johansson, Rolf Johansson, 2008, "Model Predictive Control for Scheduling and Routing in a Solid Waste Management System", Proceedings of the 17th World Congress the International Federation of Automatic Control Seoul, Korea, July 6-11, 2008.
20. S.P. Gautam, P.S. Bundela, A. K. Pandey, M.K.Awasthi and S. Sarsaiya, 2010, "Composting of Municipal Solid Waste of Jabalpur City", Global Journal of Environmental Research 4 (1): 43-46,2010 ISSN 1990-925X © IDOSI Publications, 2010.

21. Talyan, V., Dahiya, R.P., Sreekrishnan, T.R., 2008. State of municipal solid waste management in Delhi, the capital of India. Waste Management. 28, 1276-1287
22. United Nations Environment Programme (UNEP), 2005. Solid Waste Management, vol. I, ISBN: 92-807-2676-5.
23. Wolfsberger, T., Pinkel, M., Polansek, S., Sarc, R., Hermann, R., Pomberger, R., 2016. Landfill mining: Development of a cost simulation model. Waste Management & Research. 34: 356-367.
24. Wilson, D.C., 2007. Development drivers for waste management. Waste Management and Research 25, 198–207.
25. Xiaoyun Bing , Jacqueline M. Bloemhof , Tania Rodrigues Pereira Ramos , Ana Paula Barbosa-Povoa,Chee Yew Wong, Jack G.A.J. van der Vorst, 2015, "Research challenges in municipal solid waste logistics management", http://dx.doi.org/10.1016/j.wasman.2015.11.025.
26. Zurbrügg, C., Schertenleib, R., 1998. Main problems and issues of municipal solid waste management in developing countries with emphasis on problems related to disposal by landfill. Presented at Third Swedish Landfill Research Symposia, Luleå, Sweden, and October 1998.
27. Mariana Soares Maciel Machado Magalhães, "Route Optimization for the Solid Waste Collection"https://paginas.fe.up.pt/~ee05135/MT/MT%20%20Mariana%20Magalhaes%20(050503135).pdf.
28. Amirhossein Malakahmada,*, Putri Md Bakria, Munirah Radin Md Mokhtara,
29. Noordiana Khalila, "Solid waste collection routes optimization via GIS techniques in
30. Ipoh city, Malaysia", https://www.sciencedirect.com/science/article/pii/S1877705814010005
31. Danijel Marković, Dragoslav Janošević, Miomir Jovanović, Vesna Nikolić, "APPLICATION METHOD FOR OPTIMIZATION IN SOLID WASTE MANAGEMENT SYSTEM IN THE CITY OF NIŠ "http://facta.junis.ni.ac.rs/me/me201001/me201001-08.pdf.
32. *Mr. Ankit Verma* and Prof. B.K Bhonde*** **,** "Optimisation of Municipal Solid Waste Management of Indore City using GIS", https://www.researchtrend.net/ijet/ijet31/36%20ANKIT%20VERMA.pdf.
33. Mohana Taneja#1,Archana Paranjpe#2,"MSW USED AS ENERGY RECOVERY IN JABALPURCITY", http://www.ijater.com/Files/6e2b4d67-f7f04e7e975d4c9a522718 44_IJATER_35_03.pdf
34. NIKOLAOS V. KARADIMAS MARIA KOLOKATHI GERASIMOULA DEFTERAIOU VASSILI LOUMOS , "MUNICIPAL WASTE COLLECTION OF LARGE ITEMS OPTIMIZED WITH ARC GIS NETWORK ANALYST " , http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.462.6532&rep=rep1&type=pdf
35. **Jabalpur Municipal Corporation, Madhya Pradesh, India With Sacramento County, California, USA , "**Improved solid waste management in Jabalpur, a case study **" , http://www.umcasia.org/uploads/Citylinks_Jabalpur_case_study_Improved_solid_waste_management_in_Jabalpurpdf.pdf.**
36. A.V.Bhambulkara * Isha.P. Khedikarb** , "MUNICIPAL SOLID WASTE (MSW) COLLECTION ROUTE FOR LAXMI NAGAR BY GEOGRAPHICAL INFORMATION SYSTEM(GIS)" ,
37. Hareesh K.B1 , Manjunath N.T 2 , Nagarajappa D.P.3 , "Route Optimization of Municipal Solid Waste for Davangere City Using GIS " , https://www.ijirset.com/upload/2015/june/5_Route_NEW.pdf
38. CHRISTOS CHALKIAS, KATIA LASARIDI ,Department of Geography , "Optimizing municipal solid waste collection using GIS " , http://www.wseas.us/elibrary/conferences/2009/vouliagmeni/EELA/EELA-03.pdf.
39. Central Public Health and Environmental Engineering Organisation (CPHEEO),MUNICIPAL SOLID WASTE MANAGEMENT MANUAL**. http://sac.ap.gov.in/sac/UserInterface/Downloads/MSWMReports/Book%202.pdf.**