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Route Optimisation for Solid Waste Management Using Geo-Informatics

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Abstract: *Due to rapid industrialisation, population of Chandrapur city of Maharashtra state of India is increasing day by day, hence increasing the solid waste generation. Around 0.25 kg /person/day solid waste is generated and around 80 ton wastes are dumped in dumping site daily. Collection and transportation is one of the important functional components of solid waste management. Thus, to keep city clean and environmentally healthy, the management of solid waste has now becoming an important issue. Geo-informatics is proposed to determine the minimum cost/distance efficient collection paths for transporting the solid wastes to the dumping site. This uses information on population density, waste generation capacity, road network, storage bins and collection vehicles etc.*

This paper attempted to optimise the route for collection and transportation of municipal solid waste of the city using geo-informatics technique. Initially all ancillary data have been collected from various sources. Using hand held GPS, the position of the entire dust bin in the city are collected and the data are converted into shape file. The roads are digitised from the road network map of the municipal corporation. From the shape file of existing road network, network database for the entire road are prepared using Arc-GIS 9.2. Taking capacity of solid waste carrying vehicle into consideration, the routes are optimised for each trip of vehicle and total distance to be travelled is calculated for each trip. Finally cost is compared for solid waste disposal using this technique with the existing system of Municipal Corporation. From the analysis and results, it is concluded that the Geo-informatics technique gives better accuracy for route optimisation and can be used as a decision support tool by municipal authorities for efficient management of the daily operations for transporting solid wastes, load balancing within vehicles, managing fuel consumption and generating work schedules for the workers and vehicles for overall cost minimisation.

Keywords: *Geo-informatics, ancillary data, GPS, network database, Municipal Corporation.*

I. Introduction

Land, water and air- these three elements form the basis of human life and human activities. One of these activities is transportation of people, goods and material for industry, commerce and recreation. Transportation is about movement from one place to another and, therefore, is a fertile ground for geospatial technology and applications, which can range from route planning to position location, navigation, asset management and surveillance. The story of human progress has a huge chapter on exploration and commerce. The hunger for new land led to the discovery of the Americas. The search for an alternative to the risky land route to India for spices and silk led to the search and discovery of a route from Europe via the aptly named Cape of Good Hope. While land travellers were guided by way points, sailors depended on the stars and the sun. The sextant provided a measure of the latitude but it required a determined and somewhat eccentric clock maker named Harrison to devise a means to determine the longitude.

Technological development, globalization and population growth have accelerated the dynamics of the urbanization process in developing countries. The rapid growth rates of many cities, combined with their huge population base, has left many Indian cities deficient in infrastructure services like water supply, sewerage and solid waste management(SWM). Due to a lack of serious efforts by town/city authorities the management of garbage has become a tenacious problem, notwithstanding the fact that the largest part of any municipal expenditure is allotted to it.Waste collection and transportation is the contact point between the waste generators (residential, commercial and industrial establishments) and the waste management system, and this relationship needs to be carefully managed to ensure an effective system. The environmental impact caused by municipal solid waste has received special social and environmental attention in recent decades. Regardless of the size, the socio-economic traits and the complexity of a municipality's waste management program, the disposal of municipal solid waste is a growing concern throughout the world. In recent years, as the population is increasingly concentrated in cities and due to a number of cost, health and environmental concerns, many municipalities have been forced to assess their solid waste management program and examine its cost-effectiveness in terms of collection, transportation, processing and disposal. A review of the literature concerning the cost of municipal solid waste management shows that due to the multiplicity of influencing factors, costs are a very complex issue. Location characteristics, the quantity of the solid waste, its composition,

the type of technology utilized the collection and transportation, distances and labour/landfill expenses are examples of factors that have a great effect on the cost of solid waste management. Therefore, the collection and transportation of solid waste in urban areas is a very difficult and complicated problem. It has been estimated that, of the total amount of money spent for the collection, transportation, and disposal of solid waste, approximately 60–80% is spent on the collection phase (Municipality of Athens, 2003). Therefore, even a small improvement in the collection operation can result to a significant saving in the overall cost.

The present study mainly focused on the use of geo-informatics technique for collection and transport of solid waste from any loading spot in the area to disposal site using optimised route for particular bins. Therefore, a framework for the design and implementation of a solution for the solid waste collection and transport is proposed so that saving in the overall cost of SWM can be achieved. The entire paper has organised into five parts. Part I discusses the introductory part while study area and data resources used for this research is described in part II. Overall methodology is given in part III whereas Part IV discusses the analysis and results followed with conclusions in part V.

II. Study Area And Data Resources Used

2.1 Study area

Chandrapur town of Maharashtra state of India is lying on topo-sheet 56M/5, is an industrial town covering an area of 56 km^2 situated in west of Maharashtra state, India. Chandrapur has 61 wards and 74,900 households, with an average number of occupants per house of 5. The entire city is subdivided into 11 zones. It is estimated that the city produces 80-90 MT of domestic solid waste daily. Presently, the existing 751 types A and types B community bins at selected places are being used for primary storage. The waste materials are transported using, 7 dumper placer and 10 tractors with trolley for disposal in open space at the outskirts of the city. About 13.42 million rupees annually are expended for the entire solid waste disposal process, without any proper collection and transportation system.

The detailed supportive data on waste collection statistics of chandrapur city is given in Table 1.

Table 1: Solid waste data of Chandrapur City

Sr No.	Particulars of solid waste	Value
1	Solid waste generation rate	0.250 kg/capita/day
2	Quantity of domestic solid waste	90 MT/day
3	Total number of community bins	751
4	Total annual expenditure for SWM	Rs 13.42 million
5	Total number of supervisory staff	7

Source: municipal corporation chandrapur, 2011

The map of study area with its boundaries and road network is shown in figure 1a and 1b respectively.

Figure 1 a

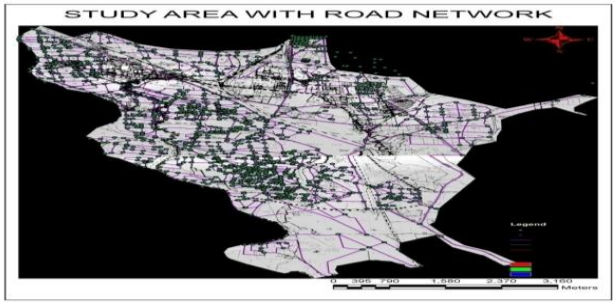

Figure 1b

Figure 1: Map of study area

2.2 Data resources and software used:

For this research paper data resources used are enlisted in table 2.

Table 2: Description of data resources used

1	Data Used	TOPO-sheet 56M/5 Location mapRoad network mapEasting/ northing of bin location Solid waste carrying vehicle details.
2	Software used	Erdas-Imagine 9.1 Arc-GIS 9.2 GPS (Magellan make)

III. Methodology

Methodology used in this research paper is described stepwise as follows

- Data such as population density waste generated, Municipality boundary map, Existing road network map, storage bins and collection vehicle details were collected from Municipality Chandrapur for digitizing roads of city and locating the dustbin position according to its easting and northing.
- Topo-sheet (56M/5) was collected from Irrigation department for rectification of municipality map and road network map according its latitude and longitude.
- Geo-referencing of toposheet was done using ERDAS Imagine 9.1.
- Rectification of Municipality map and road network map using UTM WGS-84 co-ordinate system using topo-sheet.
- Road network map was exported in GIS.
- Position (Easting and Northing) of solid waste bin location using hand held GPS were collected and the data was exported in GIS.
- From road network, network dataset was prepared using ARC-catalogue of ARC-GIS 9.2.
- The Optimized route for solid waste collection and disposal using network analyst tool of ARC-GIS 9.2. was analyzed.
- Cost analysis and comparison with existing expenditure of municipality was then analyzed.

IV. Analysis and results

From the map of study area all the roads were digitized using ARC GIS 9.1 and all the attributes were created in shape file as shown in fig. 2. Using shape file of digitized road, road network of the area was generated in ARC Catalogue as shown in fig.3.

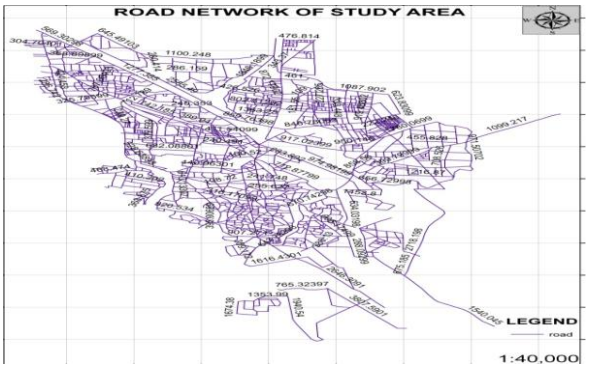

Fig.2. Road network of study area

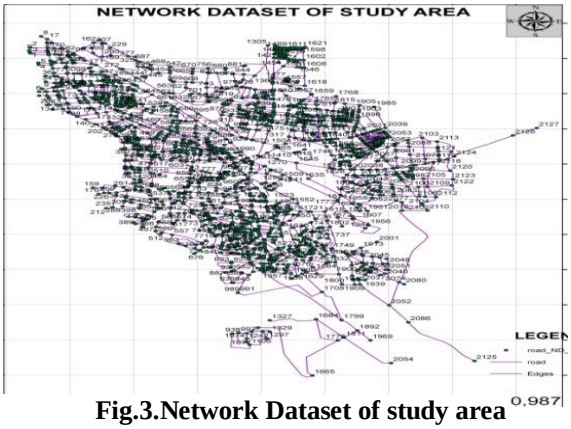

Fig.3.Network Dataset of study area

Solid waste collection bins locations were collected for entire town using GPS survey and was converted into shape file in Arc-GIS. From the network dataset generated, the routes were optimized from solid waste storage bin to disposal site (dumping yard) for all 11 zones lying in the study area using network analyst tool of ARC GIS. All the attributes corresponding to optimised routes were generated. For optimisation stops, barriers, nature of the roads was taken into consideration. The optimised route for zone 1a is shown in fig 4, whereas its attribute is enlisted in table 3.

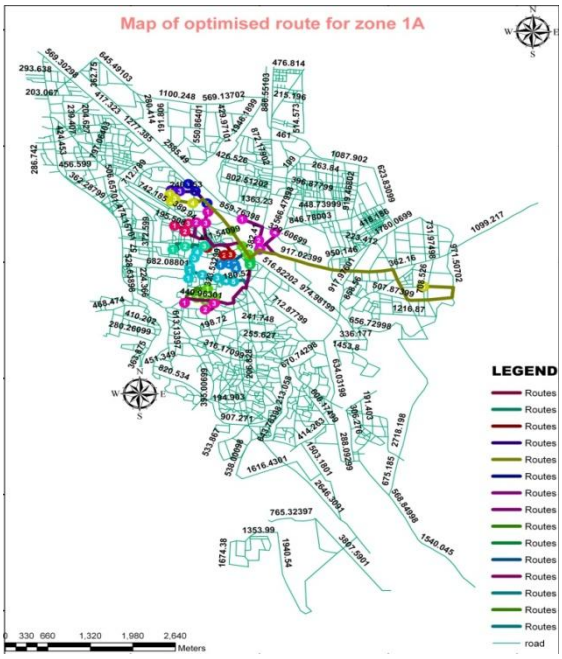

Fig.4. Map of optimised route for zone 1 a

Similarly routes were optimised for all zones of each type of storage bins and all the required attributes were obtained which is summarized in table 4 and the total expenditure required was calculated and the comparison of this expenditure after route optimization was made with the existing expenditure spend by the municipal corporation was carried out as shown in table 5.

TABLE 3: Description of route optimised and vehicles required for zone 1A (for type b bin)

Sr. no.	Route optimised for container	Distance to be travelled from source to dumping site in KM	Average speed of vehicle in KM/hr	Total time to be taken for one trip in hr.	cumulative time	Total trip required for one day
1	Navratra Ground, CEO Bunglow, Collector Bunglow	6.06	20	0.303+(0.16)x3+0.284=1.067	1.067	
2	Wasade, Kanyaka Bank , Vitthal Typing	5.84	20	0.292+(0.16)x3+0.24=1.012	2.079	
3	Taxi Stand, Bus Stand, Erani,Tipnis	5.47	20	0.27+(0.16)x4+0.24=1.15	3.229	
	One Hour Rest			1	4.229	
4	Sanjay Gandhi Market, Parate, Post Office	4.79	20	0.23+(0.16)x3+0.20=0.91	5.139	
5	Indira Nattyagruha, Hansan Pump,Jilla Parishad, Railway Quarter	4.44	20	0.22+(0.16)x4+0.24=1.1	6.239	1 day /Vehicle
6	Mutton Market, Dawabazar,Salfale, Vishvabharati	5.19	20	0.25+(0.16)x4+0.28=1.17	7.409	

7	Pode, Hislop College, Junghare, Jatpuragate Gen Toilet,Kanzi	5.65	20	0.28+(0.16)x5+0.3=1.56	1.56	
8	Jotiba School, Samarat Chowk, Gaikwad	6.46	20	0.32+(0.16)x3+0.27=1.07	2.63	
9	Vternity Hospital, Papamanjil, Chor Khidki, Chorkhidki Gen. Toilet	6.68	20	0.334+(0.16)x4+0.28=1.25	3.88	
	One Hour Rest			1	4.88	1 day /vehicle
10	Luthale, Musale, Bonde, Shakuntala Appartment	5.88	20	0.29+(0.16)x4+0.23=1.16	6.04	
11	Patwari Office, Janta School, Wasalwar	5.268	20	0.263+(0.16)x3+0.24=0.983	7.023	
12	R.T.O Office, Kundojwar, B&C Quarter	5.81	20	0.29+(0.16)x3+0.255=1.02	8.043	
13	Engg. College, Duradkar, B&Cquarter	5.82	20	0.29+(0.16)x3+0.28=1.05	1.05	
14	Sindhi Colony, Peon Colony, T.B.Hospital	5.73	20	0.28+(0.16)x3+0.26=1.02	2.07	
15	Khoja Colony, Puri, Borgamwar	6.13	20	0.30+(0.16)x3+0.28=1.06	3.13	1 day /vehicle
	One Hour Rest			1	4.13	
16	Behind Iti, Salmankhan, T.B.Hospital	6.79	20	0.33+(0.16)x3+0.26=1.07	5.2	
17	Dahalkar Bunglow , Stediumslope, Diware Bunglow, Anty Corruption	6.34	20	0.32+(0.16)x4+0.28=1.24	6.44	

Total vehicles trips required = 9 No. /week, Vehicles required per year = 432.
Total expenditure required= Rs. 733968 (Rs. Seven lakh thirty three thousand nine hundred and sixty eight).

Table 4 : Description Of Vehicles And Amount Required After Route Optimization

Sr.No.	Zone	No. of Vehicles required per year	Amount to spent for solid waste disposal in Rs	Total Amount in Rs
1	1A TYPE B BIN	432	733968	
2	1B TYPE B BIN	432	733968	
3	2 TYPE B BIN	576	978624	
4	3A TYPE B BIN	288	489312	
5	3A TYPE A BIN	432	474768	
6	3B TYPE B BIN	288	489312	62,88,624/-
7	3B TYPE A BIN	432	474768	
8	4A TYPE B BIN	288	489312	
9	4A TYPE A BIN	432	474768	
10	4B TYPE A BIN	288	489312	
11	4B TYPE B BIN	288	460512	

Table 5: Comparative Statement Of Amount Spent And Required After Route Optimization

Year	Amount spent	Amount to be spent after optimization	Saving
2008-2009	7719223	-	-
2009-2010	8977225	-	-
2010-2011	10881358	-	-
2011-2012	13425300	62,88,624/-	53.15 %

V. Conclusion and Discussions

From the analysis of data and the results obtained the following conclusions are drawn.

Geo-informatics proves to be powerful tool for route optimization for solid waste disposal. Using Geo-informatics solid waste disposal management can be carried out efficiently. This technique saves approximately 50% expenditure to be incurred on SWM but requires skilled persons initially to perform this optimization task and assigned the routes to the concerned vehicles. The technique can also be used as a decision support tool by municipal authorities for efficient management of the daily operations for transporting solid wastes, load balancing within vehicles, managing fuel consumption and generating work schedules for the workers and vehicles for overall cost minimisation.

It is further recommended that DGPS survey should be carried out to locate the exact position of bins as hand held GPS works for 5-10 m accuracy. Slope should be considered while assigning path to the vehicles as it affects on speed of vehicles as well as its moving directions.

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