ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

Route Optimization of Municipal Solid Waste for Davangere City Using GIS

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ABSTRACT: The population growth in many urban cities and its activities in developing countries have resulted in an increased solid waste generation rate, an important issue. In the process of solid waste management system; collection and transport play a leading role in waste collection and disposal in which, collection activities contributed the most of total cost that is paid for solid waste collection activities by city's citizen and transport activities are required 60-70% of total cost that is the total expenditures spent on the transport, transfer, disposal and treatment of municipal solid waste (MSW) by city authorities. Hence optimizations of routing system, systematization of collection, transport and transfer activities are the important components for an effective MSW management system. This project describes the current problems and the improvement of the waste management activities in a city of Davanagere. An integrated solid waste management assessment model is proposed and used as a decision support tool by municipal solid waste management authorities for daily efficient operations such as collection/transport path management, load balancing within vehicles, fuel consumption management by using GIS application. In addition, a simple optimal routing model is proposed to achieve the minimum cost/distance/time efficient collection and transport path for municipal solid waste management.

KEYWORDS: Municipal solid waste management, Waste collection, Route optimization, GIS.

I. INTRODUCTION

Solid wastes are being produced since the early stage of the civilization. During the early period solid wastes were conveniently and unobtrusively disposed off. As the density of population was low and large open land population explosion was available, disposal was not an acute problem. With the advent of industrialization and urbanization, problems of waste disposal increased. Generally the term "waste" implies that it is of no concern to anyone and is of no value. The intrinsic value of the material as a resource or as an object of further utility has not been fully recognized. The net result is to reduce the expenditure involved for its disposal by meager allocation of resources.

Most urban areas in the country are plagued by acute problems related to solid waste management. It is estimated that about 1, 00, 000 MT of solid waste is generated everyday in the country. Per capita waste generation in major cities ranges from 0.2 kg to 0.6 kg. The collection efficiency ranges from 50 to 90% only, leaving the balance unattended. It is estimated that the urban local bodies spend about Rs.500 to Rs.1500 per ton on solid waste for

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ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

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collection, transportation, treatment and disposal. About 60-70% of this amount is spent on collection, 20 to 30% on transportation and less than 5% on final disposal of waste. Therefore waste collection must be regarded as an important issue in order to increase the efficiency of waste management.

As in the case of many cities of Karnataka, Davangere city municipal council has adopted open transportation of the waste from the temporary storage to the disposal site. Waste collected from various secondary containers and open collection points were loaded to the collection vehicles manually. Manual loading was found to be time consuming and reduce the productivity of the vehicles. Solid waste stored in the secondary containers and the open areas along the route was transported to the disposal yard every day from the prime residential areas, commercial streets and markets. But in some wards, waste was transported to the disposal yard only in alternate days. The local body is clearing the waste in two shifts per day. It is necessary to optimize the collection route so as to minimize fuel consumption, labour requirement, in turn to function in an economical manner.

II. STUDY AREA

The study area Davangere city is situated in central part of of Karnataka located at around 260 km from Banglore on Pune Banglore National Highway No. 4. It is situated at longitude of 75°55'E and latitude 14°28'N with an altitude of 550m from mean sea level. The average rainfall is around 500mm. the temperature of the city is generally varies from maximum of 41°C to minimum 16°C to the west of the Davangere city River Thungabadhra flows at around 15km distance.

The city area is about 60.88 sq.kms and population of the city as per the 2011 census is 4,35,172 and an floating population of 10,000(Source: City Municipal Corporation). The city has been converted as district head quarters in 1997 and as Municipal Corporation from 2008.

The city is divide into 41 wards and the total number of houses 11,8352. In addition to these commercial complexes, hospitals and industries are established in and around the city which add up to solid waste generation.

III. METHODOLOGY

A. GIS WORKFLOW MODEL

A model using GIS technology is developed for selecting suitable locations for secondary containers in Davangere city. GIS analysis is used to show how proposed location of the waste bins can serve the entire area. However, the following steps have been considered developing this model.

The approach essentially involves database preparation, plotting secondary containers, service area covered by the containers, route mapping for vehicle movement and analyzing the routes for optimal path.
For the analysis of placement of secondary container and generating the optimal routes and for collection of solid waste, the following data are obtained from the City Municipal Council.

1. Study area boundary
2. Detailed urban plan of the municipality
3. Number and type of vehicles used and its capacity.
4. Road network of the study area
5. Number of secondary containers and their location.
6. Capacities of secondary containers.
7. Waste generation details at each container.
8. Existing collection routes for the dumper placers.
9. Time taken for collection and disposal of solid waste.
10. Vehicle speed, fuel consumption of the dumper placers.

For the optimization of collection process a spatial geo-database is designed and implemented using a standard commercial GIS environment, Background spatial data for road network, existing routes and secondary containers locations are obtained from the Municipal Council, Davanagere. These data are updated with field work and other non

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spatial data such as secondary container number, secondary container type/capacity collection time, vehicle average speed and travel time.

A flowchart portraying the methodology involving GIS technology adopted present study is appended as figure 1 the data processing has been carried out in QGIS software has been used for the following activities.

1. Geo-referencing of Davanagere City Map
2. Digitization of Road Network
3. Plotting of Secondary container locations
4. Route mapping for vehicle movement.
5. Analysis for optimal path
6. Plotting service area covered by each container
7. Analyze the existing containers
8. Replacement & locating additional container.
9. Optimal path analysis II

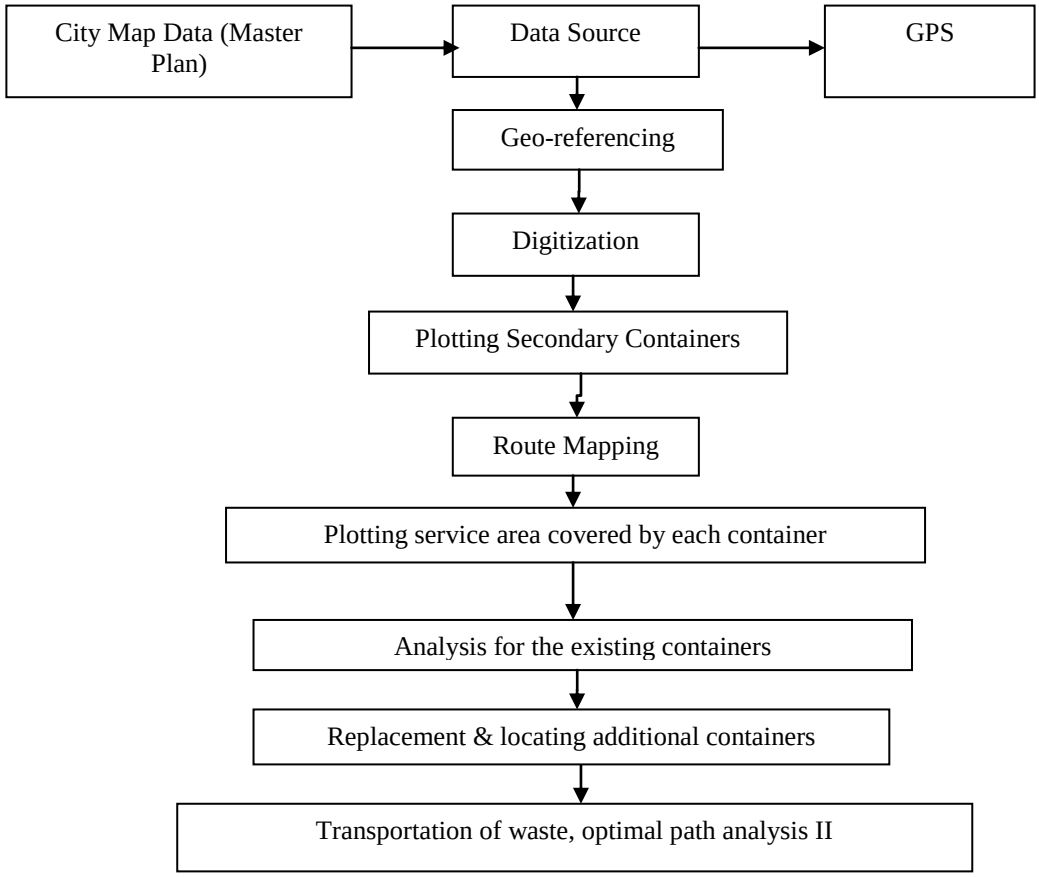

Fig: 1 A flowchart describing the methodology adopted in the present study

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ISSN (Print): 2347-6710

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B. DIGITIZATION

Davangere boundary, municipal boundary and road network was digitized using the geo-referenced master plan of the city to create the digital database.

C. EXISTING CENTRALIZED SYSTEM

There is an existing landfill site for treatment of municipal solid waste management at Avargolla with on 33.19 acres of land. At present all municipal solid waste collected in Davangere city is sent to this compost plant.

There are few lacunas existing in the present system, and they are,

- The dust bins located do not serve the entire area, which has to serve.
- They do not follow optimized route path.
- Overlapping of routes persists
- Due to overloading at the landfill site, at-site(s) time increases.

D. PROPOSED CENTRALISED SYSTEM

In this project we have identified the above lacunas, analyzed the present system and have proposed new optimal routes for centralized system.

Few steps are followed in laying the optimized routes,

1. The location of dustbins are determined keeping in mind, various factors such as
   - Population
   - Municipal solid waste generated
   - Location
   - Area to be served
2. Optimized routes are laid according to rules of CPHEEO manual
3. Time required for each trip is calculated using the formula
4. Finally cost analysis is done and comparison between the existing and proposed centralized system is done.

E. PROPOSED DECENTRALIZED SYSTEM

Since the existing landfill site far from the study area, therefore it is very difficult and uneconomical to move that all types of waste to the existing landfill site. Moreover it is understood that the selected areas contributing more organic waste, instead of transferring that organic waste to the landfill site, so it's better to make use of that organic waste into an onsite compost site is proposed at selected wards.

F. CALCULATIONS OF TIMES PER TRIP

The time required per trip, which also corresponds to the time required per container is equal to the sum of the pickup, at-site, and haul times, time is a factor accounting for off-route activities, and is given by the following,

$$T_{hcs} = \frac{P_{hcs} + s + h}{(1-w)} \quad \ldots\ldots\ldots (1)$$

Where,

T_{hcs} = time per trip for hauled container system, h/trip
P_{hcs} = pickup time per trip for hauled container system, h/trip
S = at-site time per trip, h/trip
H =haul time per trip, h/trip
W = off-route factor, expressed as fraction

While the pickup and at-site times for hauled container systems are relatively constant, the haul time depends on both haul speed and distance. From an analysis of a considerable amount of haul data for various collection vehicles, it has been found that the haul time 'h' may be approximately by the following expression:

$$H = a + bx \quad \ldots\ldots\ldots (2)$$

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Where,

H = total haul time, h/trip
a= empirical constant, h/trip
b = empirical constant, h/ml
x= round trip-haul distance, ml/trip

Substituting equation-2, in equation -1, the time per trip can be expressed as follows:

$$T_{hcs} = \frac{(P_{hcs} + s+a+bx)}{(1-w)}$$

IV. RESULTS AND ANALYSIS

A. COMPUTATION OF WASTE GENERATION

The population of the study period (2011) was collected from the municipality, the records of 2011 senses. The base year 2011 is selected for the calculation of solid waste generation. Per-capita waste generation rate as done from the field study by the municipality is 0.47 kg, which is well between the ranges of generation rate in Indian cities.
The average waste generation rate in Davanagere city is 0.47 kg/capita/day.
Waste generation = population *per capita waste generation

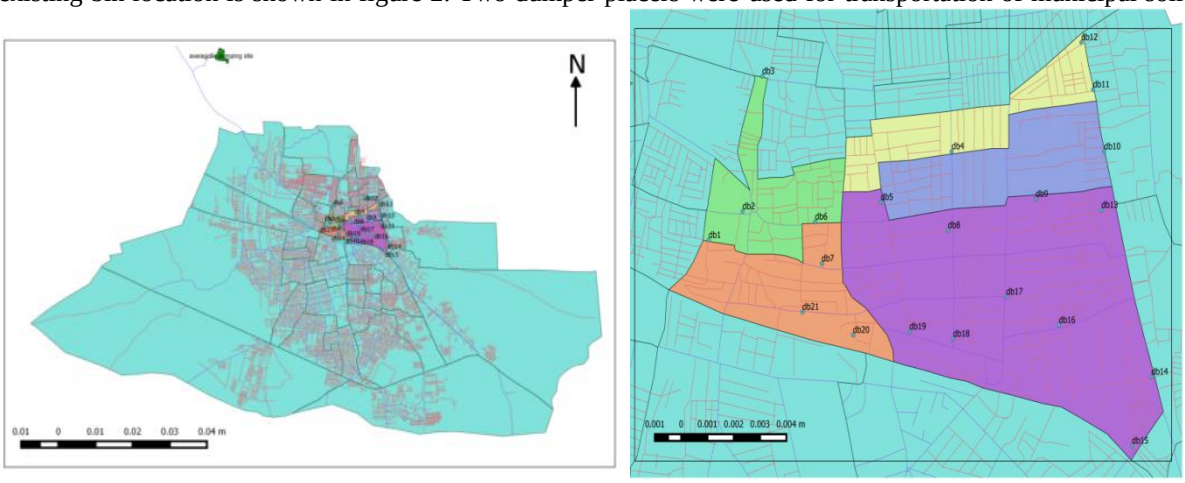
=4,35,172*0.47

= 204530.84kg/day

= 204.53 TPD

B. EXISTING CENTRALIZED SYSTEM

The existing centralized system consisted of 21 dust bins and individual route for each of the bins. The existing bin location is shown in figure 2. Two dumper placers were used for transportation of municipal solid waste..



(a) (b)

Fig 2: (a) Davangere city map, (b) Existing dust bin location

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

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The distance and time calculations are tabulated in table 1

Table: 1Route details for existing centralized wards

Route no.	Carrying dust bin	Ward	Total distence (Km)	Time/trip
R1	db1	11	15.064	0.991294
R2	db2	11	15.032	0.990353
R3	db3	11	14.804	0.983647
R4	db4	12	16.92	1.045882
R5	db5	16	16.14	1.022941
R6	db6	11	15.28	0.997647
R7	db7	17	15.76	1.011765
R8	db8	16	16.66	1.038235
R9	db9	16	17.22	1.054706
R10	db10	13	18.66	1.097059
R11	db11	12	17.8	1.071765
R12	db12	12	17.6	1.065882
R13	db13	16	18.16	1.082353
R14	db14	16	19.44	1.12
R15	db15	16	20	1.136471
R16	db16	16	18.04	1.078824
R17	db17	16	17.46	1.061765
R18	db18	16	17.1	1.051176
R19	db19	16	16.72	1.04
R20	db20	17	16.64	1.037647
R21	db21	17	16.06	1.020588

C. PROPOSED CENTRALIZED SYSTEM

Considering the lacunas in the existing centralized system, a new centralized system is being proposed by relocating the bins and laying new routes for a 5 wards. The details of the wards are as shown in table2 and their map is shown in figure3.

Table 2: Features of 5 wards.

Ward No.	Ward Name	Area (sq km)	Population 2011	SW generated (kg/day)
11	Ganesh pet	0.1762	6957	3269.79
12	Basavaraj pet	0.178	9582	4504.95
13	Chamaraj pet	0.233	8458	3975.26
16	Mandipet	0.848	6298	2960.06
17	Kayi pet	0.226	8428	3961.16

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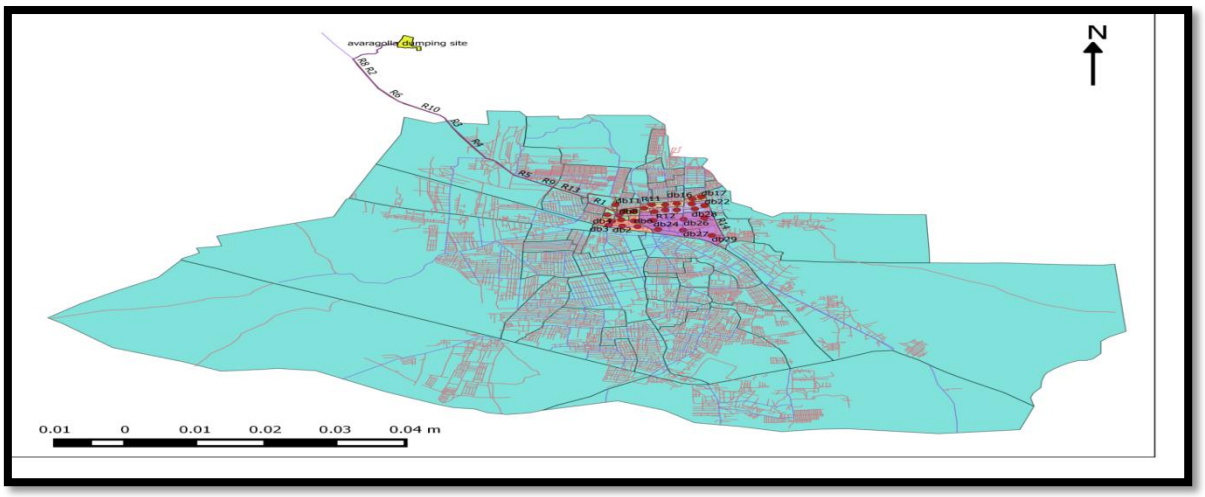

Fig 3: Optimal routes for proposed centralized system

D. OPTIMAL ROUTE

The optimal route for the secondary containers is laid starting from the centralized land fill site situated in Avargolla to each dustbin and is as shown in figure3.

Table 3: Route details for proposed centralized wards

Route no	Carrying dustbins	Ward no.	Dust bin 1	Dist from DP to db(Km)	Dust bin 2	Dist from db to db(Km)	Dist from db to DP	Total	Time/trip
R1	db8,db7	11	db8	7.406	db7	0.203	7.32	14.929	0.987324
R2	db11,db9	11	db11	7.487	db9	0.43	7.52	15.437	1.002265
R3	db12,db10	11& 12	db12	7.952	db10	0.32	7.69	15.962	1.017706
R4	db5,db6	17	db5	7.608	db6	0.21	8	15.818	1.013471
R5	db4,db3	17	db4	7.563	db3	0.14	7.68	15.383	1.000676
R6	db1,db2	17	db1	8.257	db2	0.26	7.91	16.427	1.031382
R7	db13,db14	12	db13	8.118	db14	0.25	8.57	16.938	1.046412
R8	db19,dp18	13	db19	8.355	db18	0.23	8.15	16.735	1.040441
R9	db15,db20	12& 13	db15	8.4	db20	0.18	8.78	17.36	1.058824
R10	db21,db22 ,db23	13	db21	8.842	db23	0.48	9.03	18.352	1.088
R11	db16,db17	12	db16	8.76	db17	0.28	8.82	17.86	1.073529
R12	db26,db24	16	db26	8.6	db24	0.48	8.14	17.22	1.054706
R13	db25,db27	16	db25	8.323	db27	0.48	8.83	17.633	1.066853
R14	db28,db29	16	db28	9	db29	0.86	9.47	19.33	1.116765

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E. COMPARISON BETWEEN EXISTING AND PROPOSED CENTRALISED SYSTEM. COST ANALYSIS

The cost analysis for the existing and proposed centralized system was carried out and is tabulated in table4 and table5

Table 4: Cost analysis for existing centralized routes

Route	Distence(Km)	Diesel required(liters)	Cost(Rs) Cost/trip
R1	15.064	3.766	197.715
R2	15.032	3.758	197.295
R3	14.804	3.701	194.3025
R4	16.92	4.23	222.075
R5	16.14	4.035	211.8375
R6	15.28	3.82	200.55
R7	15.76	3.94	206.85
R8	16.66	4.165	218.6625
R9	17.22	4.305	226.0125
R10	18.66	4.665	244.9125
R11	17.8	4.45	233.625
R12	17.6	4.4	231
R13	18.16	4.54	238.35
R14	19.44	4.86	255.15
R15	20	5	262.5
R16	18.04	4.51	236.775
R17	17.46	4.365	229.1625
R18	17.1	4.275	224.4375
R19	16.72	4.18	219.45
R20	16.64	4.16	218.4
R21	16.06	4.015	210.7875
Total	**356.56**	**89.14**	**4679.85**

Table 5: Cost analysis for proposed centralized routes

Route	Distence(Km)	Diesel required(liters)	Cost(Rs) Cost/trip
R1	14.929	3.73225	195.943125
R2	15.437	3.85925	202.610625
R3	15.962	3.9905	209.50125
R4	15.818	3.9545	207.61125
R5	15.383	3.84575	201.901875
R6	16.427	4.10675	215.604375

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ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

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R7	16.938	4.2345	222.31125
R8	16.735	4.18375	219.646875
R9	17.36	4.34	227.85
R10	18.352	4.588	240.87
R11	17.86	4.465	234.4125
R12	17.22	4.305	226.0125
R13	17.633	4.40825	231.433125
R14	19.33	4.8325	253.70625
Total	**235.384**	**58.84**	**3089.41**

It is found that the cost of proposed centralized system is 1.5 times lesser than the existing centralized system as shown in table 6

Table 6- Comparison between existing and proposed centralized system

SYSTEM	TOTAL DISTANCE(Km)	DIESEL(liters)	COST(Rs) Cost/day
EXISTING CENTRALIZED	356.56	89.14	4679.85
PROPOSED CENTRALIZED	235.384	58.84	3089.41

V.CONCLUSION

- The collection efficiency was increased from 75% to 100%
- A new concept called collection bins with lesser capacity was introduced in places where considerable amount of waste is not generated and does not require secondary bins.
- The cost of proposed centralized system is **1.5 ti**mes lesser than the existing centralized system.
- Waste generated from markets is purely organic instead of mixing with the other waste can be collected and transported separately to the vermi compost plant to produce good quality manure.

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ISSN(Online): 2319-8753
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