ROUTE OPTIMIZATION OF COMMUNITY SOLID WASTE MANAGEMENT IN SELECTED WARDS OF BANGALORE CITY USING GEOLOGICAL INFORMATION SYSTEM (GIS)

Basavaraj N Itnal[1], S M Prakash[2]

[1]*Research Scholar, Jain University, Bangalore, India*
[2]*Principal, KNS Institute of Technology, Bangalore, India*

Abstract

Community solid waste management is an important issue in India due to the inherent challenge it is posing as urbanization is on the rise. Currently in India as well as in many urban cities and its activities the population growth has resulted in an increased community solid waste generation rate. Bangalore is the largest city and business capital of Karnataka state. The population of the city as per the 2011 census is 8,443,675 with the total number of houses 2,101,831 A part from infrastructural development going on for sustainable development MSW management should also be taken care off. In the present study community solid waste management collection, transportation and disposal cost plays an important role about 65-75% of total cost. Hence, in Bangalore city four wards were selected to study the community solid waste management system and also optimizations of routing system, collection procedure, transport and transfer activities. Geographical Information System is a device introduced to plan for waste management and also quickly implemented to overcome community solid waste management limitation. This paper attempts to analyze the existing status of transportation of location of municipal waste along with the various secondary routes followed for the solid waste collection of selected wards of Bangalore under BBMP. In the present study, using Arc GIS, a proper optimizing the waste transportation routes and segregation of waste for efficiency in distance travelled and time taken. The clusters are made by taking the time into account, which may be plus or minus the total working hours for the day. In addition, a simple optimal routing system is proposed to achieve the minimum cost/distance/time efficient collection and transport path for community solid waste management as well as social and environmental implications.

Key words: *community solid waste management, GIS, route optimization, transportation.*

---***---

INTRODUCTION

Currently, the environmental issues are heading due to improper disposal of community solid waste towards a potential risk. It is an important sensitive issue which are concerns about serious environmental difficulties in today's world as well as in India. Present situation describes a serious impact of environmental pollution causing a health related problem due to improper community solid waste management and also tremendous growth in population (AshtashilVrushketuBhambulkar, 2011).

The solid waste includes non-liquid waste materials generated through human activities includes domestic, commercial, agricultural and industrial and from public areas. Solid waste is generated by eight most important activities like residential, industrial, commercial, institutional, construction, municipal services, and process and agricultural. It classified as different materials and includes dust, food waste, paper, metal, plastic, glass and other discarded cloths, garden waste, hazardous waste and radioactive waste (Pruss, *et al.*, 1999).

Generally, due to increase in population is related to increase in community solid waste generation rate and directly related to per capita income of community (Wang, *et al,* 2011). In currently community solid waste management has become a major challenge in world and India, especially urban areas. The community solid waste generation from various human activities directly affects the health and negative impact on the environment (Bhambulkar, 2011). Al Ansari, *et al,* (2012) estimated in their study due to waste related disease 10% of the person lost their life.

Geographical Information System (GIS) is a very important tool for identifying the dumping yard and rout mapping including proper community solid waste management practices. Geographical Information System (GIS) is handling spatial data including non-spatial variables also recognize and analyze the relationship between spatial and mapped phenomenon (MeenaDeswal and Laura, 2014).
Currently, in India especially in urban areas a class of a big problem is route optimization (Frank Schweitzer, *et al.*, 1997). This work is an attempt to minimize the current routes distance and time which will resulted in availability of existing equipment and labour to perform separate collection of recyclable waste in the town as well as social and environmental implications.

Materials and Methods:

Study Area:

Bangalore lies at having latitude 13^{0}02’00.90``N and longitude $77^{0}$34’32.17``E with an altitude of an average of 839 to 962 meters from mean sea level. The average rainfall is around 859 mm. The coolest month is December with an average low temperature of 15.4 °C and the hottest month is April with an average high temperature of 36 °C, generally varies from maximum of 37°C to minimum 13.0°C. The city covering an area of 709.49 Sq.km and population of the city as per the 2011 census is 8,443,675 and floating population of 12,000. The city is divided into 198 wards and the total number of houses 2,101,831 (source BBMP). In addition to these commercial complexes, hospitals and industries are established in and around the city which add up to solid waste generation. Bangalore is the planned city in India with a population of 8.4 million in 2011. Bangalore is the fifth most populous city in India and the 18^{th} most populous city in the world. Bangalore was the fastest-growing Indian metropolis after New Delhi between 1991 and 2001, with a growth rate of 38% during the decade. The entire management of solid waste is taken care by Bruhath Bengaluru MaganagaraPalike (BBMP). The corporation of the city is making efforts to devise plans and strategies for management of solid waste in an efficient manner.

In the present study four of the wards was selectedRadhakrishna temple (ward no 18), Sanjay Nagar (ward no 19), Ganga Nagar (ward no 20)and Hebbala (ward no 21). Location map of the study area is given in Figure 1. Nearby areas are Lottegollanahalli, Venkatachary Nagar, HIG North By Outer Ring road colony, RMV II stage, Dollar apartment, Krishna Layout, Amarajyothi Layout (P), Raj Mahal Vilas 2^{nd}Stage 3^{rd}Block, Naidu Layout (P), Judicial colony, AECS Layout, Jaladarshini Layout, Geddalahalli.

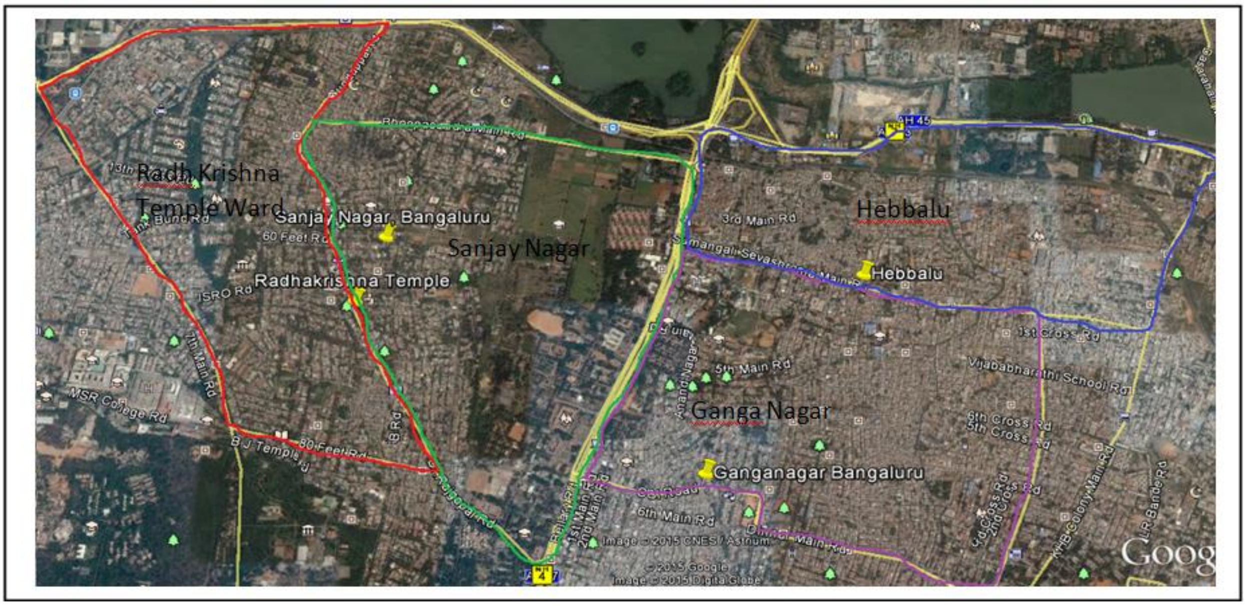

Figure 1. Map showing selected wards

Table 1. Area under each Ward

Ward Number	Ward name	Ward covers an area
18	Radhakrishna Temple	Gokula, Muthyalamma, Mattikere, Yeshwantpura and Mohan Kumar Nagar
19	Sanjay Nagar	Sanjay Nagar, BEL, MSR Nagar, Boopasandra, and MS Ramaiah Circle
20	Ganga Nagar	Ganga Nagar,
21	Hebbal	Amarjyothi Nagar and Hebbal,

Methodology

GIS instrument was used to import, manage and analyses spatially based data. The three steps used in the present study spatial data were collected, identify the collection point including segregation and finally optimization of routes, minimum time and distance (AnkitVerma and Bhonde (2014), the methodology adopted in the present work is given in Figure 2. To process and analyze information on the basis for the proposed methodology according to Alvarez, *et al.*, (2008).

To understand the spatial geo database standard commercial GIS software was used (ESRI, Arc GIS). Available spatial data for road network, existing routes, collection points and geographical boundary were obtained from BBMP. These data were updated with field data and other non-spatial data such as road name, road type, vehicle average speed, travel time, house number, bin capacity, collection time are added.

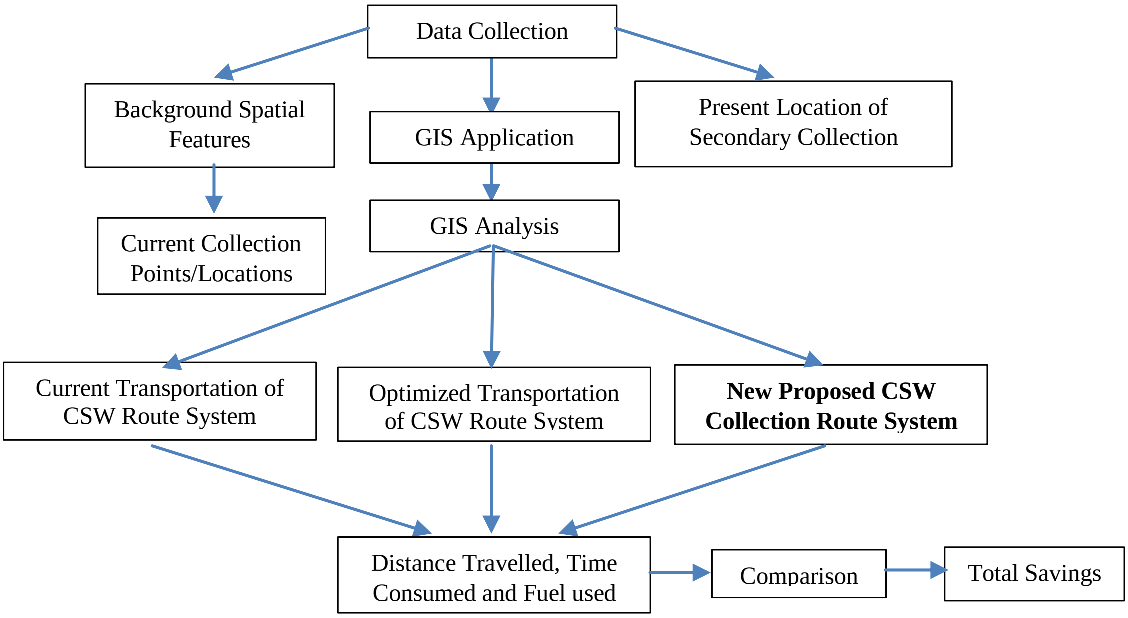

Figure 2. Methodology adopted in the present Study

Results and Discussion

The demography the study area and data collected was collected from the BBMP, the records of 2011 senses. The base year 2011 is selected for the calculation of community solid waste generation. Per-capita community waste generation rate as computed from the field survey by the municipality is 0.45 kg, which is well between the ranges of generation rate in Indian cities. The average community waste generation rate in selected wards of Bangalore city is 0.42 kg/capita/day.With the help of GIS and field survey this map is taken showing the existing and optimized route system of the selected wards. The details of the selected wards population, households and total area covered is given in Table 2.

Table 2. Ward wise list of community solid waste generation rate with Population

Ward no	Area Sq. Km	Population 2011	Households, 2011	Population 2015 (projected)	MSW generation	
					Per capita rate (kg/c/day)	Daily generation Tonnes/day
18	1.9	35122	9058	37685	0.42	15.82
19	1.5	32491	8153	39472	0.42	16.57
20	2.3	27361	6592	32882	0.42	13.81
21	1.2	32516	8181	39505	0.42	16.60

The population of the study period (2011) was collected from the BBMP, the records of 2011 senses. In the present study to calculate waste generation the base year 2015 is selected. Per-capita waste generation rate as done from the field study by the municipality is 0.42 kg, which is well between the ranges of generation rate in Indian cities. The average waste generation rate in the selected wards of Bangalore is 0.42 kg/capita/day. Waste generation in the selected wards is = population *per capita waste generation (149544 *0.42 = 62808.48 kg/day) is equal to 628.08 TPD) CMSW generated in selected wards of Bangalore.

Table 3. Ward wise list of Degradable, recyclable and other waste generation rate

Locations	Hebbal Division (Wards), Tonnes/day			
	R K temple	Sanjay Nagar	Ganga Nagar	Hebbala
Quantity of Degradable waste generated	13.80	13.74	12.42	14.05
Quantity of Recyclable waste generated	1.32	1.53	1.28	1.45
Other waste includes Fine earth	0.70	1.30	0.11	1.09
Storage Area	Dumping yard Doddamankalala near Sakkaregollahalli village 72 km from the wards			

Table 3 gives the ward details and types of waste generated in the selected wards. 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.

From the data base of community houses were identified using GIS, four wards were selected for the present study. Presently in the study area no bins were provided for primary collection. With the help of GIS and field survey the map is taken showing the door to door collection route map of Community Municipal Solid Waste (CMSW) in the study area is given in Figure 1 the type of collection vehicles used for collection and segregation of CMSW is given in Table 3.

The major roads and the heavy vehicles areselected from the spatial data. The order in which the number of vehicles have to be used is calculated based upon the quantity of waste. Then theoptimal path is generated for each vehicle. In this process,clusters of bins are formed and each cluster is allocated to avehicle. The clusters are made by taking the time intoaccount, which may be plus or minus the total workinghours for the day (Figure 1 and Table 5). The last cluster may need less time ifthe quantity of waste to be transported is less. In such cases,the last cluster may be merged with other clusters byincreasing the total working hours (AnkitVerma and Bhonde, 2014).

Present study reveals that the total sum of distance covered by fully loaded compactor is 189.21 km to and pro, while optimized distance covered is 164.75 km, which is less by 24.46 km per day. In this work optimize the solid waste route for vehicle in selected wards of Bangalore by using Arc map. With the GIS technique, optimum route was identified which found to be cost effective and less time consuming when compared with the existing run route. The route is to be obtaining by Arc GIS is 189.21 km. and time is 12.0 Hr. 60 min. The costs for these operations are 99322.80 rupees per day. The cost is save up to 1.15 % per day (Larsen, et al.,2009).

Table 6 revealed 12.95 % reduction in travelled length and 12.92% saving in collection cost. The optimal collection was Rs. 86,490=60 per day (Hareesh, et al., 2015). In the current practice in selected wards of Bangalore employed four (15 numbers with 4 trips) vehicles, with operating cost of approximately Rs. 99,322=80.

Table 4. Time and distance existing systems for selected wards of Bangalore

Route No	SW Carrying Vehicle	Ward	Total Distance, km	Time, s
GNA1	CV 1	20	12.560	3093.1
GNA2	CV 2	20	10.832	2667.6
GNA3	CV 3	20	7.965	1961.5
GNA4	CV 4	20	8.459	2083.2
GNA5	CV 5	20	12.624	3108.9
HA1	CV 6	21	10.692	2633.1
HA2	CV 7	21	6.548	1612.6
HA3	CV 8	21	8.459	2083.2
HA4	CV 9	21	8.921	2197.0
SNA1	CV 10	19	6.826	1681.0
SNA2	CV 11	19	7.962	1960.8
SNA3	CV 12	19	4.365	1075.0
SNA4	CV 13	19	9.256	2279.5
SNA5	CV 14	19	4.236	1043.2
SNA6	CV 15	19	3.695	910.0
SNA7	CV 16	19	8.362	2059.3
SNA8	CV 17	19	3.245	799.1
RKA2	CV 18	18	6.569	1617.7
RKA3	CV 19	18	8.896	2190.8
RKA4	CV 20	18	7.562	1862.3
RKA5	CV 21	18	8.695	2141.3
RKA6	CV 22	18	8.235	2028.0
RKA7	CV 23	18	9.245	2276.7
Total			**189.21**	**45364.7**

From the map of the selected wards in the present study area all the roads were taken using ARC GIS and all the characteristics were created in shape file as shown in Figure 1. The optimal route for the secondary containers is placed starting from the centralized land fill site situated in Doddamankalala near Sakkaregollahalli to each stations and is as shown in Figure 2.

The comparative study (Table 6) reveals that the optimal solution route proposed for route corresponds and improvement when compared to the existing route. The improvement is more emphatic in terms of the total travel time in the optimal route, defined as the runtime of the collection vehicle plus collection time for the waste. Route distance and time savings become all more important when considered on a monthly and yearly basis. Waste is collected 4 times per day for secondary route, resulting to a total of 4 collection trips per day. Thus a large amount of time and distance is saved by the optimized routes (Figure 3) (Kadam Puja Chandrakant and Hema Pate (2015).

Present study reveals that, by encouraging the public through awareness campaign through school, education, segregation should be in the house to house collection, individual involvement and involvement of local NGOs.

Table 5. Time and distance (in km) optimal systems for selected wards of Bangalore

Route No	SW Carrying Vehicle	Ward	Distance	SW Carrying Vehicle	Distance b/w Routes	Total	Time, s
GNA1	CV 1 & CV 2	20	14.896	CV 2	1.265	16.161	3980.07
GNA2	CV 3 & CV 4	20	12.365	CV 4	1.523	13.888	3420.16
HA1	CV 5, CV 6 & CV 7	20 & 21	21.365	CV 7	2.543	23.908	5887.76
HA2	CV 8 & CV 9	21	14.523	CV 9	1.214	15.737	3875.51
SNA1	CV 10, CV11 & CV12	19	15.621	CV 11	2.658	18.279	4501.52
SNA2	CV 13 & CV14	19	11.625	CV14	0.986	12.611	3105.68
SNA3	CV15, CV16 & CV17	19	12.682	CV16	2.894	15.576	3835.86
RKA1	CV18 & CV19	18	13.576	CV18	1.245	14.821	3649.93
RKA2	CV20 & CV21	18	14.698	CV20	0.998	15.696	3865.41
RKA3	CV22 & CV23	18	16.872	CV23	1.205	18.077	4451.77
Total						**164.75**	**40574.71**

Table 6. Comparison between existing and optimal systems for GRA

		Existing	Optimal
1	Total Community Solid Waste Generated tons/day in the selected wards	628.08	628.08
2	Total number of collection vehicles required per day	15 (4 trips)	15 (4 trips)
3	Total vehicle distance travelled for collection per day (km)	189.21	164.75
4	Travel time for collection of CMSW per day (s)	45364.71	40574.71
5	Costing of hiring of CMSW collection vehicles	1655.38 trip	1441.54 trip
6	Diesel requirement, Liters	31.535	27.458
7	Cost per day,Rs.	99322.80	86490.60

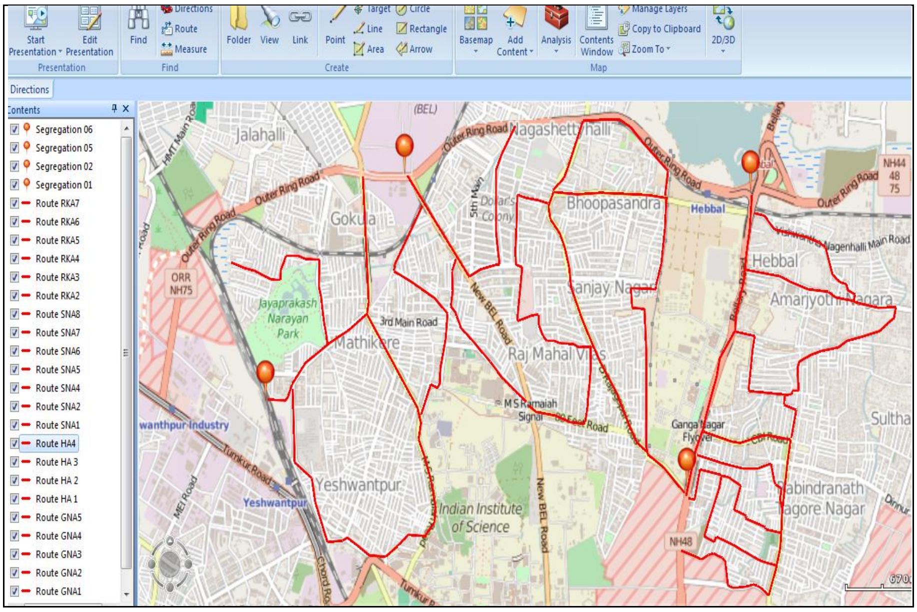

Figure 1. Base Map of the Primary collection for CMSWin the study area

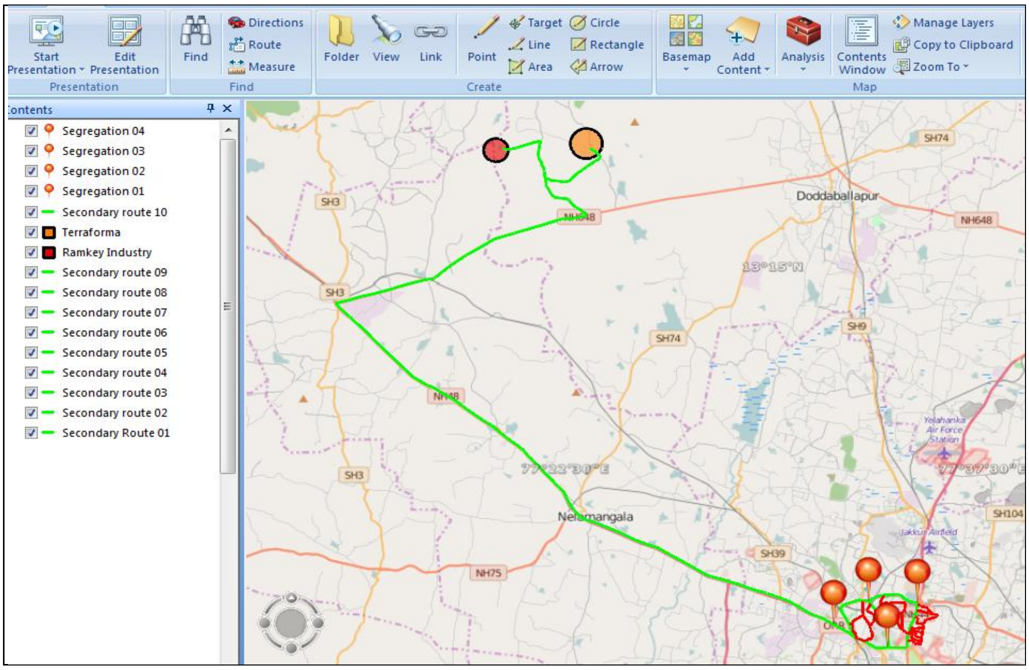

Figure 2. Existing route for Community Municipal Solid Waste from Segregation point to Dumping Yard

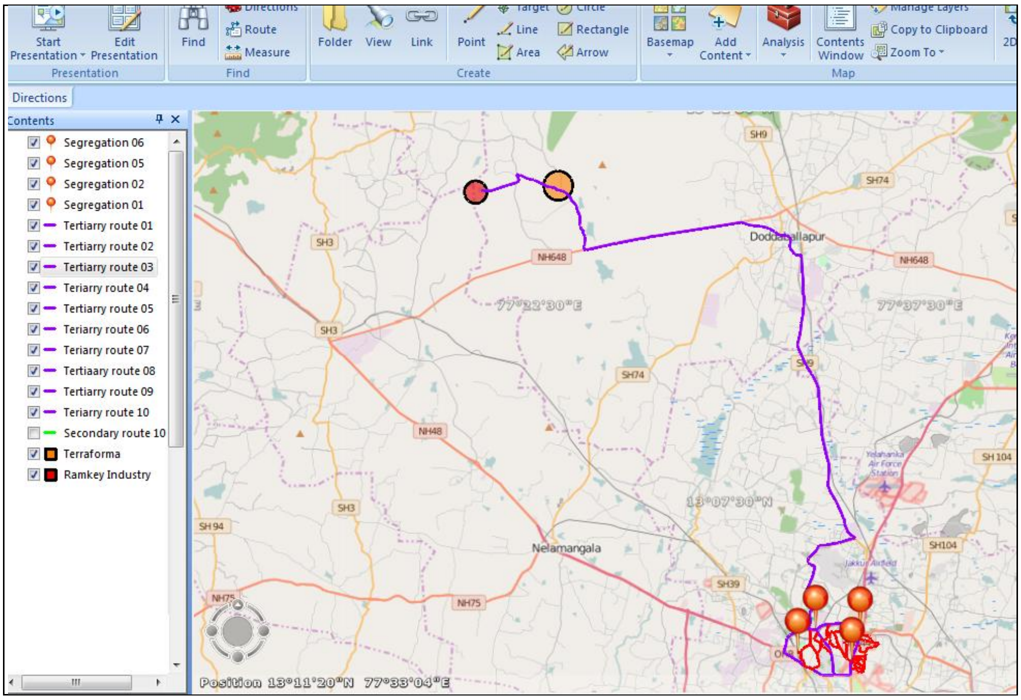

Figure 2. Optimized route for Community Municipal Solid Waste from Segregation point to Dumping Yard

CONCLUSION

The present study attempts to optimize the routes for transport of solid waste from the few selected wards in Bangalore 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 ina most economic transport model. The study revealed 12.95 % reduction in travelled distance and 12.92% saving in operational cost. The reduced travel time of the trucks would directly lead to reduced environmental hazard.

The GIS optimal routing model has been developed by considering the parameter like population density, waste generation capacity, road network and transporting waste from transfer station to Doddamankalala near Sakkaregollahalli disposal and handling site.In the present study reveals that, BBMP can use this optimized route map as decision support tool for resourceful management of transporting the community solid waste, fuel consumption and vehicle in daily route of life.

REFERENCES

[1] Al-Ansari, N.K, Hanbali, A. Al and Knutsson, S. (2012). Locating Solid Waste Landfills in Mafraq City, Jordan. Advance Science and Engineering Research, 2(1), 40-51.

[2] AnkitVerma and B.K Bhonde (2014).Optimization of Municipal Solid Waste Management of Indore City using GIS. International Journal on Emerging Technologies 5(1): 194-200.

[3] AnkitVerma and B.K Bhonde. (2014) Optimisation of Municipal Solid Waste Management of Indore City using GIS International Journal on Emerging Technologies 5(1): 194-200.

[4] AshtashilVrushketuBhambulkar. Municipal solid waste collection Routes optimized with arc GIS network analyst. (2011) International Journal of Advanced Engineering Sciences and Technologies, Vol. No. 11, Issue No. 1, 202 – 207.

[5] Bhambulkar, A.V., (2011). Municipal Solid Waste Collection Routes Optimized with ARC GIS Network Analyst. Advanced Engineering Sciences and Technologies, 11(1), 202-207.

[6] Frank Schweitzer, Helge Rose, Werner Ebeling. (1997). Optimization of Road Networks using Evolutionary Strategies.

[7] Hareesh K.B, Manjunath N.T and Nagarajappa D.P, 2015.Route Optimization of Municipal Solid Waste for Davangere City Using GIS. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 6.

[8] Kadam Puja Chandrakant and Hema Pate (2015).Optimization of Solid Waste Management using Geographic Information System (GIS) for ZoneA under PimpriChinchwad Municipal Corporation (PCMC),International Journal of Science and Research (IJSR) Volume 4 Issue 6.

[9] Larsen, A., Vrgoc M., & Christensen T. (2009).Diesel consumption in waste collection and transport and its environmental significance.Waste Management and Research.27, 652-657.

[10] Lopez Alvarez J V, Aguilar Larrucea M, Ferna´ndez-Carrio´nQueroS,Jime´nez del ValleA.optimizing the collection of used paper from small businesses through GIS techniques: the leganes case (Madrid, Spain). Waste Manage 2008;28:2-282.

[11] MeenaDeswal and J.S Laura, (2014).Application of GIS in MSW management in India. International Journal of Engineering Research and Development, Volume 10, Issue 10, PP.24-32.

[12] Pruss A, Giroult E, Rushbrook P (eds) (1999). Safe Management of Waste from Health Care Activities.World Health Organization, Geneva, Switzerland.

[13] Wang, H., He, J., Kim, Y., and Kamatta, T., (2011). Municipal Solid Waste Management In Small Towns: An Economic Analysis Conducted in Yunnan, China. Policy Research Working Paper, 57-67.