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# Applications of Geospatial Technologies in Solid Waste Management Planning for Ranchi City: Sustainable Development Perspective

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**Abstract—***In past decade, Geospatial Technology has witnessed expansion in the scope of environmental management, solid waste being just one of them. Remote Sensing and GIS has vast areas of application in solid waste management and planning. Ranchi city has a population of 10.07 lacs as per Census of India, 2011. Ranchi city witnessed urban and commercial growth after the creation of Jharkhand in 2000. Ranchi city lacks adequate infrastructure for handling solid waste being generated from within the municipal area. Open dumping at Jhiri is observed largely by RMC. In this research work, authors attempt to identify new solid waste disposal site using overlay tools in GIS platform using multiple criteria's. The new sites identified carries higher scores as compared to Jhiri. Vehicle route networking in GIS platform is used to identify the shortest routes. The application of these techniques by RMC will reduce the environmental impacts of waste disposal on land, water and human life. Further the economics of vehicle routing can be adequately managed by adopting these route networks. With environmental perspective, shortest routes will result in reduced emission of atmospheric pollutants thereby addressing environmental health and sustainability. Thus, in this research a comparison of the old facilities and new facilities, and old route and new route is discussed that will be useful for policy makers as Ranchi has been selected under smart city project initiated by Government of India.*

**Keywords***: Network Analysis, Overlay analysis, GIS, City Planning, Environmental Management.*

## 1. INTRODUCTION

Municipal solid waste generation is increasing in exponential rate with population growth **[1, 2]**. Municipal authorities of different cities fail to manage such huge quantities of waste due to lack on environmental infrastructures, technical gaps and failures in planning. The industrial evolution and economic transformation had accelerated production and consumption of packaged materials and results in massive production of solid waste. Most countries are struggling to deal with growing waste problems **[3, 4]**. In India, door to door collection and segregation has not yet been implemented successfully resulting in open dumping of waste within urban peripheries. Local Municipal Corporation or Municipal Authorities are responsible for the management of waste generated which includes waste collection, transport, treatment and disposal. Municipal authorities expends a large fraction (85%) of their budget in MSW collection and improvement in the design of collection system will result in a substantial savings **[5]**. After collection transportation and sanitary disposal are the most important element in waste management. The intrinsic nature of MSW collection relates to the development of effective vehicle routing (VR) models that optimize the total traveling distances of vehicles, the environmental emission and the investment costs **[6]**. VR is a scheduled process that allows vehicles to load waste at gather sites (a.k.a. sites) and dispose it at a landfill with the target being oriented by a single or multiple objectives **[7]**. Further site selection criteria for scientific waste disposal is dependent of multiple criteria and their specifications such as soil type, land use and land cover, ground water depth, slope, proximity to urban areas, airports, water bodies, sensitive and protected zones etc.

In this paper, authors attempt to integrate these two aspects: Site Selection and Vehicle routing for achieving sustainable development of Ranchi city in Jharkhand. Authors have used geospatial technology in assessing these aspects for Ranchi city that has been selected under smart city project of Government of India.

Ranchi is bounded by 85°75' - 85°87' East to 23°21' - 23°87' North. The study area Ranchi Municipal Corporation consists of 55 wards with a population about 10.07 lakh **[8]**. Being the capital city of Jharkhand, residential and commercial activities are rapidly growing and thus has resulted in generation of large quantities of waste.

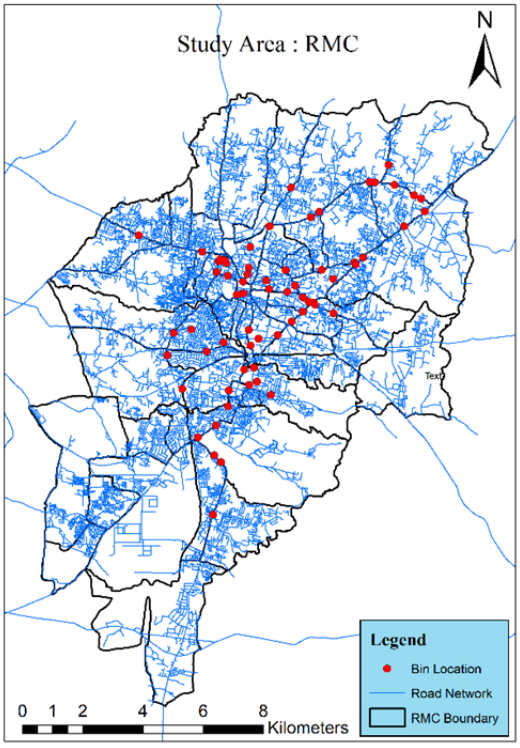


**Fig. 1: Study area**

## 2. MATERIALS AND METHODOLOGY

Base map of the study area was created using ward map, toposheets, and Google earth in GIS platform. Road network was digitized using Survey of India toposheet No F45B7 and updated using Google Earth. Detailed information about existing route and waste bins (capacity, location etc.) were collected from Municipality and was also used in calculation of shortest route and proposed route. Route optimization was conducted using network analysis tool in Arc GIS 10.4.

Weighted Overlay analysis from ARC GIS 10.4 was used along with pairwise comparison technique and multicriteria decision making to identify the new sites for waste disposal. Table 1 shows the criteria used in site selection.

For the site selection, different criteria were taken as major roads, railway lines, airport, water bodies, groundwater depth, soil, slope and land use. Spatial data for different criteria was obtained from different government sources. ArcGIS 10 software is used to create different spatial layers. Different landfill siting criteria were considered for this study and buffer maps were created for each criterion with critical constrains. Weightage of each layer is derived from pairwise comparison method. Slope, Soil, Water Table, LULC was given 24%, 36%, 14% and 9% respectively. Distance from road, railway and airport was given 5%, 3% and 9% respectively. For weighted overlay analysis, all the layers are reclassified in a common scale to normalize the values of different layers. This can be done by giving weight and ranking to all prepared layers. All the layers were standardized in a common scale of 1 to 5 (value 5= most suitable, value 4= moderate suitable, 3= less suitable, 2= unsuitable and 1= most unsuitable). This ranking of suitability criteria is done as per the various guideline proposed by institutions i.e. CPCB, CPHEEO etc. Weighted overlay analysis was performed in ArcGIS 10.4 software to find suitable landfill site.

Route optimization was done in ArcGIS 10.4 software using Network Analyst extension. Road network and location of waste bins, dumping site, mini transfer stations

**Table 1: Data and Source**

| S. No | Data/Material | Source |
|---|---|---|
| 1 | Land Use Land Cover Map | National Remote Sensing Agency |
| 2 | Soil Map | National Bureau of Soil Science, Nagpur, India |
| 3 | Slope Map | ASTER DEM, NASA |
| 4 | Groundwater Table | Central Ground Water Board, India |
| 5 | Distance from Road | Google Earth Imagery |
| 6 | Distance from Railway | Google Earth Imagery |
| 7 | Distance from Airport | Google Earth Imagery |

used as input data in network analyst. New route and Vehicle Routing Problems are the different methods used to solve the problem **[9]**.As per the data provided by RMC, there are 11 routes which functions daily to collect the solid waste. Using the New Route method distance was calculated from different origin points within the city to the dumping site. A comparison of existing and proposed route was discussed in following section.

## 3. RESULTS AND DISCUSSION

As a result of weighted overlay analysis, a suitability map was produced, having areas marked as most unsuitable, unsuitable, less suitable, moderate suitable and most suitable. Based on the final suitability map a total 476 suitable patches were found. The area ranges from 2.08 to 90 hectares. A total of 476 sites have been identified but with reference to socio economic studies and area requirement in 2026 and 2036, only a few have been finally selected, and those are at Hardag and Dundu.

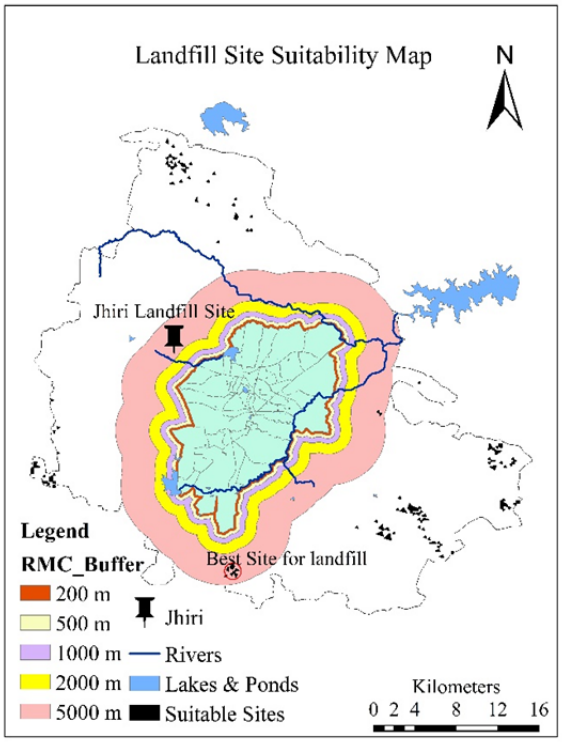


**Fig. 2: Suitable Landfill site**

Among all other selected site these identified patches fall in distance range (2-5 Km), soil class (fine loamy), groundwater depth (2-4 MBGL), land use (barren land) and in reasonable distance from Airport, Railway and road network. This prediction also helps in identifying areas that are more suitable for LS and thus decision makers can implement land management approach for future use.

**Table 2: Comparison of existing and proposed routes for waste collection and transport**

| Route No. | Route Name | Existing distance (m) | Proposed distance (m) |
|---|---|---|---|
| Route1 | Rajbhawan to Argora chowk | 13163 | 10379 |
| Route2 | New market to Piska more | 8167 | 8185 |
| Route3 | New market to Booti more | 16771 | 16090 |
| Route4 | Rajbhawan to Kantatoli | 11695 | 11785 |
| Route5 | Kutchery to Overbridge | 12935 | 12284 |
| Route6 | Firayalal to Kokar | 13101 | 12949 |
| Route7 | Sarjana to Dangra toli | 11231 | 11102 |
| Route8 | Argora to Hinoo | 15757 | 14559 |
| Route9 | Argora to Airport | 16387 | 10449 |
| Route10 | Sujata to Kantatoli | 13900 | 11368 |
| Route11 | Kantatoli to Khelgaon | 15849 | 14829 |
| **Total Distance** | | **148956** | **133979** |

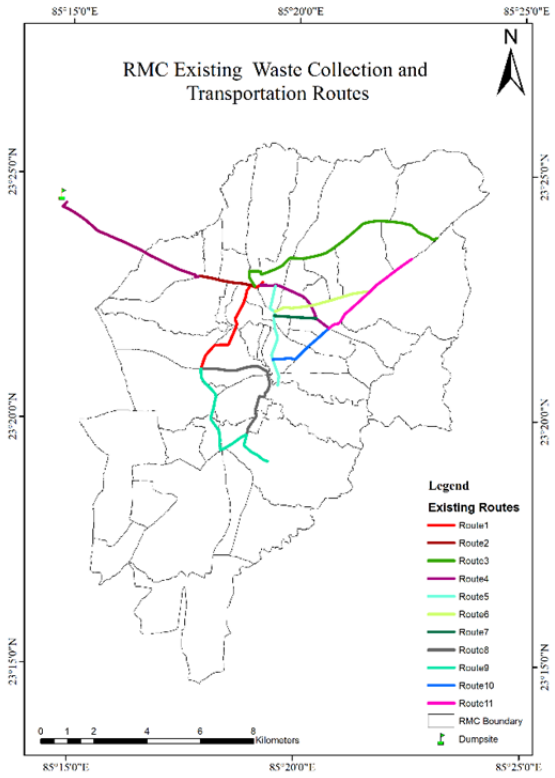


**Fig. 3: Existing waste collection route**

## 4. ECONOMIC ASPECT:

The proposed route is 10% less in distance than the existing route for waste transport and collection, i.e. 14977 meters. This implies approx. 5400 Km yearly less travel resulting in savings of 32400 INR assuming vehicle mileage 10Km/L and fuel cost 60INR/L.

$$\boldsymbol{D_y = [\{\Sigma_E - \Sigma_P\} * 30 * 12]}$$

$D_y$= [{148956 – 133979} *30*12] = 5400 Km

where,

$D_y$= Yearly difference in existing and proposed route

$\Sigma_E$= Summation distance of Existing route

$\Sigma_P$= Summation distance of Proposed route

$$\boldsymbol{S_y = \frac{D_y * F_D}{M}}$$

$S_y$ = (5400 * 60) / 10 = 32400 INR/Vehicle

where,

$S_y$= Yearly savings on fuel consumption per Vehicle

$D_y$= Yearly difference in existing and proposed route/ Vehicle

$F_D$= Fuel cost (Diesel)

$M$= Mileage of vehicle used

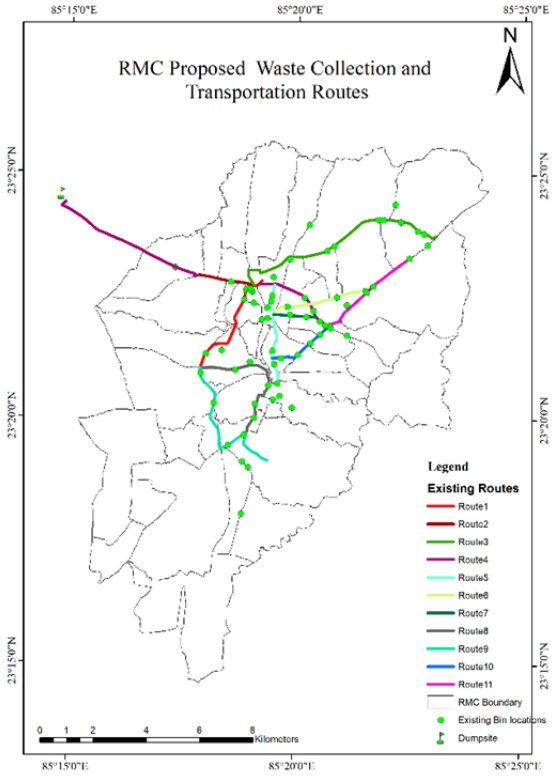


**Fig. 4: Proposed waste collection route**

## 5. ENVIRONMENTAL ASPECT:

### $CO_2$ Emission

$CO_2$ emission from a liter of diesel= 2693.12 grams **[10]**

$CO_2$ emission from 540 liters of diesel = 540 x 2693.12 = 1454.29 Kg

1454.29Kg of $CO_2$ is emitted per year can be reduced by opting the new route per vehicle.

## 6. CONCLUSION

Integrated Solid Waste management focusses on waste collection, segregation, treatment, recycle and reuse and safe disposal. Among these parameters, inefficiency in waste collection system has resulted in failure of the waste management system. The results highlight the benefits of adopting new routes both economically and environmentally. The current disposal site adopts open dumping resulting in environmental and social damages. The current study provided a new suitable landfill site which can be used as sanitary landfill up to 2036. Thus, the environmental, social and economic sustainability component of the research work is adequately addressed in this work. Ranchi Municipal Corporation and its people will be benefitted by adopting the new results and is line with the Swatch Bharat Mission-Government of India programme.

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