

Spatial Decision Support System for Solid Waste Management in Chickmagalur City

C R Ramkrishnaiah¹, Deepika B V^{2*}, Shridhara T N³

¹Associate Professor, Department of Civil Engineering, BMS College Bangalore- 560019

²Assistant Professor, SMVITM, Bantakal, Shankarpura, Udupi, Karnataka- 574115

³Asst. professor. Department of Civil Engineering NMAMIT, Nitte, Karnataka. – 574110

*Corresponding author: Deepika B V, E-mail; bv.deepika@yahoo.com

Abstract

The management of solid waste becomes more challenging in densely populated heterogeneous cultures in developing countries. The complexity of issues involved in municipal solid waste management necessitates development and application of new tools capable of processing data inputs of varying formats, numerical models and expert opinion in multi objective decision making scenario. Decision support system (DDS) is among the most promising approaches to confront such situations. After adoption of municipal solid waste (Management and Handling) Rules, 2000 in India, the necessity of development of an Environmental Decision Support System (EDDS) has further increased. The DDS models should ideally be integrated with Geographical Information System (GIS) to optimize collection, transportation, processing and disposal. For proper solid waste management it is necessary to know the quantity of solid waste generated, optimized route for collection of solid waste, selection of proper disposal site. The present study develops the model for solid waste management in chickmagalur city. It illustrates the quantity of waste generated in each ward, complete ward information is updated in Arc-GIS the database used are population, ward number, area under each ward, number of containers in each ward. New disposal site is selected with reference to CPHEEO guidelines using weighted overlay analysis database used are spatial and non spatial data which includes map layers such as soil, slope, drainage, topography, land use, contour, road network etc. Optimized path is developed using Arc GIS for selected new disposal site data base used in container location. This proposed model can offer a good decision support system which can be used by municipal authorities which gives complete information of each ward, provides highly suitable disposal site with less field work and cost, simple optimal routing model is proposed to achieve the minimum cost/distance/time efficient collection and transport path for municipal solid waste management.

Keywords: Solid Waste Management, Arc-GIS, Decision Support System, Model.

1. INTRODUCTION

Rapid growth of urban population in developing countries in recent years has made MSWM an important issue. India is facing serious environmental problems in MSWM that is really threatened by a number of problems; some of which include inadequate management, lack of technology and human resources, a shortage of collection and transport vehicles, and insufficient funding.

Over the years, there has been a continuous migration of people from rural and semi-urban areas to towns and cities. The proportion of population residing in urban areas has increased from 10.84% in 1901 to 25.70% in 1991. The number of class I cities has increased from 212 to 300 during 1981 to 1991, while class II cities have increased from 270 to 345 during the same period. The increase in the population in class I cities is very high as compared to that in class II cities. The uncontrolled growth in urban areas has left many Indian cities deficient

in infrastructural services such as water supply, sewerage and municipal solid waste management [2].

Chickmagalur is the headquarters of the district of the same name. Chikmagalur is one of the important hill station located in the western part of Karnataka and situated in the backdrop of the picturesque Bababudan Mountain of the Western Ghats. Chikmagalur is the district headquarters and largest urban centre in the district. The city is very well known for coffee. The city is located at a distance of 40km from Kadur and 57km from Hassan. There are two state highways, Mangalore-Kadur at a distance of 40km. The nearest seaport & airport is Mangalore located at a distance of 124km. The city is situated at an altitude of 1021m above the mean sea level and is located on 13036' North altitude and 75045' Eastern longitude. The administrative limits of the Chikmagalur City Municipal Council encompass an area of 27.00 sq.km. The city has increased in area with inclusion of new areas into the municipal limits. There has been stress on Solid Waste Management for the city. Now the Karnataka State government has formulated a State Policy for Solid waste management. The Nirmala Nagara programme has also emphasised on Solid Waste Management for the town. A programme for improvement of the Solid waste management system is proposed for Chikmagalur city on the lines of the State Policy Solid Waste Management [3].

Presently a large proportion of the total expenditure is incurred on collection, a bit lesser on transportation & a meagre amount on disposal. City Municipal Council, Chickmagalur invests around 515 lakhs on solid waste management every year. Around 70-80% of the total expenditure on solid waste management is spent on collection, 22.5% on transportation and only 2.5% on disposal [3]. The waste generation in Chickmagalur has been estimated in the Action Plan report for solid waste management prepared by the Chickmagalur City Municipal Council. The total waste generation is estimated at 40 tons per day. 60% waste is generated from households.

Decision support systems (DSSs) are designed to help decision makers solve complex spatial problems. DSSs are computer-based information systems that use data and models to interactively support semi structured or unstructured decisions. Spatial analysis has been attempted to solve complex environmental problems through DSSs and proximity analysis. Making (good) decisions requires knowledge, intelligence, and expertise to solve the conflicts associated with specific objectives. Expert knowledge is of utmost importance for designing a DSS, especially in environments involving uncertainty [4]. Here an attempt has been made [1] to create a web based decision support tool for quantity of solid waste generation in each ward of the city[2]. To display the complete ward information using Arc GIS. [3] Selection of new disposal site for solid waste using Geospatial technology[4]. To develop a GIS based optimal solid waste collection path[5]. To establish a SDSS (Spatial Decision Support System) for managing solid waste in the Chickmagalur city.

2. METHODOLOGY

The present study develops the model for solid waste management in chickmagalur city. It illustrates the quantity of waste generated in each ward, complete ward information is updated in Arc GIS the database used are population, ward number, area under each ward, number of containers in each ward. GIS and GPS datas of each ward and each secondary container is used and geo tagging is done. New disposal site is selected with reference to CPHEEO guidelines using weighted overlay analysis database used are spatial and non spatial data which includes map layers such as soil, slope, drainage, topography, land use, contour, road network etc. Optimized path is developed using Arc GIS for selected new disposal site data base used in container location.

Computation of waste generation

The population of the study year 2011 was collected from the municipality, the records of 2011 census. 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 0.35 Kg, which is well between the ranges of generation rate in Indian cities. Waste generation in each ward was calculated by multiplying population and per capita waste generation.

Street sweeping

Presently the municipal workers are deployed to carry out street sweeping activity. As the length of the roads is more and number of workers is less, frequency of cleaning B, C roads taking place once in fifteen days or once in a month. No of workers required for street sweeping is calculated as per Manual by Directorate of municipal administration by No of workers=length of road*frequency of cleaning/No of days and total number of workers for A,B and C type road is 78Nos. According to manual by directorate of municipal administration number of brooms for each sweepers is 4 so total number of brooms required is 314.

Design of Primary Collection System

Waste would be collected from its source (domestic and commercial premises) and transported to secondary containers. Primary collection is characterized by push carts, bicycles or small vehicles and auto tippers. Pushcarts were used for door-to-door collection in each street. The collected waste from pushcarts was conveyed and emptied to the dumper bins, i.e. secondary containers.

Present situation and problem definition:

Currently ‘door to door’ collection system is not implemented in all the wards of the city. In case of some wards ‘door to door’ collection system was in practice, but due to lack of labours and residents disputes the system has stopped. So, it is in need to practice ‘door to door’ collection in the city to increase the efficiency of solid waste management.

Design of pushcarts requirements:

According to Karnataka state policy one pushcart can cover 160 houses in a shift so number of pushcart required is 177Nos. One trip can cover 40 houses Time required for one trip=90mins hence no. of trips in 6 hour shift=4 trips

Selection of disposal site:

In the selection of disposal site two types of data base are generated. They are: (a). Spatial database: It is composed of digitized maps like, landuse/land cover, geomorphology, drainage, slope, soil, DEM, etc maps used in present study are:

Table 1 different layers used for analysis

Sl. No.	Layers	Source
1.	Slope	Extracted from DEM
2.	DEM(Digital Elevation Model)	Aster
3.	Drainage	Extracted from DEM
4.	Road network	Toposheet
5.	Landuse/land cover	Satellite image

6.	Contour	Extracted from DEM
7.	soil	KRSRAC

SDSS work flow model

The design of SDSS for MSW in an urban environment must have the following capabilities GPS data's are collected, vector data's of city was collected, samplings and text files are collected. All the data's are used in software's and analysis is done to get the result in the form of maps, tables and graphs.

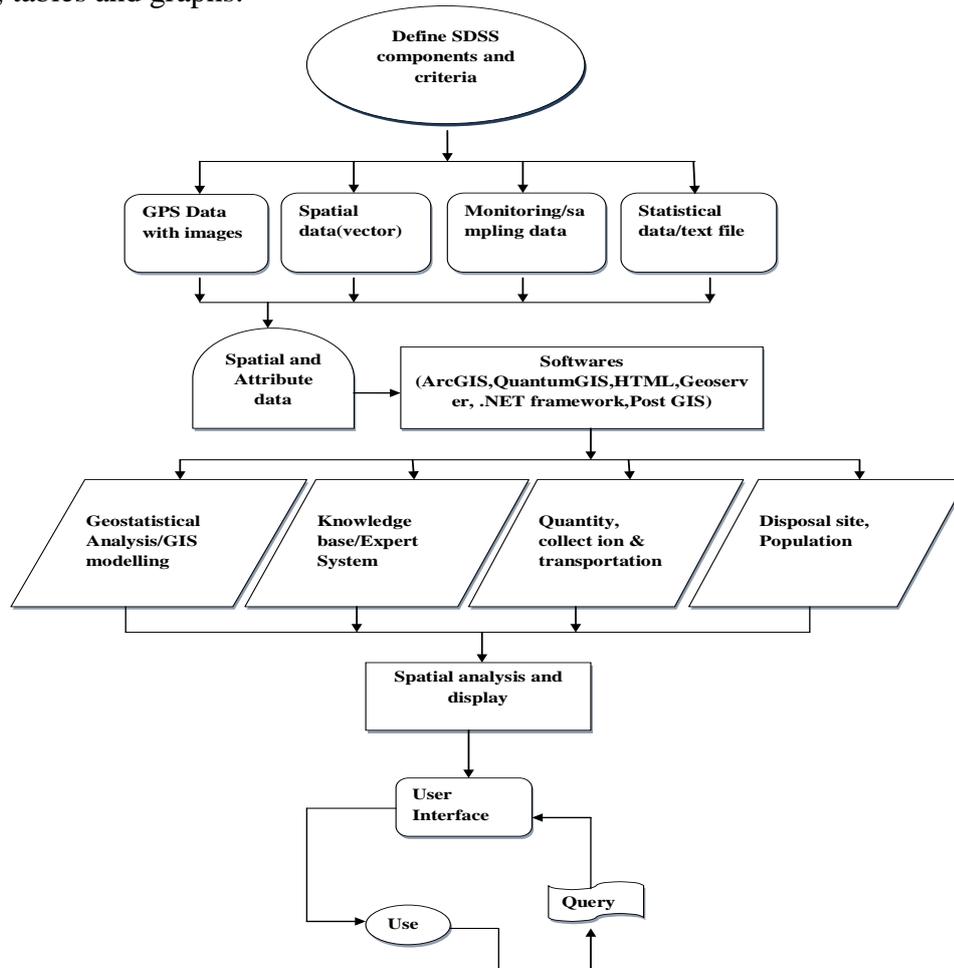


Fig. 3 Flowchart describing the methodology adopted in the present study

Computation of ward information:

Complete ward information is very much essential to take up any decisions for solid waste management. For displaying all the ward information following database is essential. After collecting all the datas quantity of waste generated in each ward is calculated using per capita waste generation and population in each ward. Geo-referencing of Chickmagalur City Map, Digitization of Road Network is done. Geo tagging of GPS datas are done. All the tabular datas are updated to attribute table in Arc GIS 9.2. This will give the complete information of each ward on clicking each ward like quantity of waste generation, population, area, number of household, quantity of containers, number of containers which is as shown in the fig 4.

Non spatial database

It is composed of municipality map with wards, population, ground water details and soil types. The base map was transformed into digital map for use in GIS by digitising using the platform of ArcView GIS software. Digitising a map means converting an analogue map into a digital form by encoding the spatial coordinates of features on the map through the process of on-screen digitising. A digital map that is recognised by the computer in a GIS environment is the end-product of this exercise.

All the parameters have been generated as a single layer in vector format using overlay analysis. Different buffers are created for each of the criteria 200m for lake, 100m for river, and 200m for highway. Disposal sites were selected from the region which is outside the buffer zone. All the parameters are given different Weightage for a total of 100%. Each parameter has different categories and the Weightage ranks for the separate category has been allotted based on its influence to the selection of solid waste disposal site. Sites were selected as suitable and not suitable. In the suitable area four sites were selected and finally one site was selected as highly suitable. The selected site is as shown in the fig10.

Table 2 Weightage given for selection of disposal site

Sl. No	Parameters	Not suitable	Suitable
1.	Water bodies	Buffer of 200m	>200m
2.	Road	Buffer of 200 and buffer above 400	200-300m
3.	Drainage	Buffer of 500m	>500 m
4.	slope	<5% and >15%	5% to 15%
5.	Contour	Buffer of 0.3	0.3-0.5
6.	Wells	Buffer of 300m	>300m
7.	Ground water table	<2m	>2m

Optimized path collection of waste from secondary container for new disposal site:

Optimized path for transportation of secondary containers is essential to reduce the fuel cost and to cover all the scheduled containers within specified period of time. The collection of waste into secondary containers has been designed and the containers are provided in suitable locations based on the quantity of waste collected, road width and availability of open spaces not creating nuisance to public, traffic and not affecting the aesthetic condition of the city. Hauled container system is used in which the containers used for the storage of wastes are hauled to the disposal site, emptied, and returned to their original location. As per CPHEEO manual 2000 Density of waste=500Kg/m³, Overflow that should be provided=100%, Quantity of waste generated=41.4tonnes, Quantity of waste after providing 100% overflow=82.8 tones , Capacity of waste=82.8/0.5 =165.6m³.No of 3m³ containers=165.6/3 =55Nos.No of 4.5m³ containers=165.6/4.5 =37Nos.Both 3 and 4.5m³ containers=165.6/(3+4.5) =22+22=44

At present there are 44 secondary containers but the efficiency of door to door collection system must be improved to increase the quantity of waste collection

A model using GIS technology was developed for obtaining the optimized solid waste collection path for new disposal site. The approach essentially involves database preparation, plotting secondary containers, route mapping for vehicle movement and analysing the routes for optimal path.

For the optimization of the collection process a spatial geodatabase was designed and implemented, using a standard commercial GIS environment. Background spatial data for road network, existing routes and secondary containers locations were obtained from City Municipal Council, Chickmagalur. These data were updated with field work and other non spatial data such as secondary container number, secondary container type/capacity, collection time, vehicle average speed and travel time.

The data processing has been carried out in ArcView 9.2 environment. ArcView 9.1 GIS software has been used for the following activities:

- Geo-referencing of Chickmagalur City Map
- Digitization of Road Network.
- Plotting of Secondary container locations.
- Analysis for optimal path

3. RESULT AND DISCUSSION

Ward information

The updated ward information in Arc GIS 9.2 is shown in the map (Figure 4)

Selection of disposal site

Different layers used in selection of disposal site are given in table I. After doing buffer analysis the suitable and unsuitable areas are found out. Four different areas are considered as suitable areas in those one site is highly suitable and optimization is done for highly suitable area

Optimization for new disposal site

GPS points of all the containers was taken and located on map. After finding out the optimal path for collection of waste from secondary container to the disposal site was found that 110kms is the optimal path. There are two dumper placer each carry two containers. There are 44 containers each dumper placer will carry two so daily there will be 11 trips of picking and dropping the container to its location. Per day a vehicle can do only 5 to 6 trips so 4 number of dumper placers are required. Two more dumper placer should be procured. Optimal path obtained after analysis is 110 Kms daily fuel cost is Rs 50, Mileage of dumper placer is 6km/l, Cost of fuel for 110km is Rs 916/-

4. CONCLUSIONS

The following conclusions can be drawn from the study,

- The proposed model can be used as a decision support tool by the municipal authorities for efficient management of the daily operations for moving solid wastes, load balancing within vehicles, managing fuel consumption and generating work schedules for the workers and vehicles.
- The proposed model could be used for selection of disposal site, optimum waste collection for the city.
- The study would be helpful in creating awareness among the people. The waste management data obtained from ArcGIS maps would be responsible for the retrieval, update and visualization of the information required.
- The proposed maps could provide municipality, Environmental engineers and decision makers with data about the present waste management system, which would be required for the improvement of the existing system and for future planning.

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agriculture layer

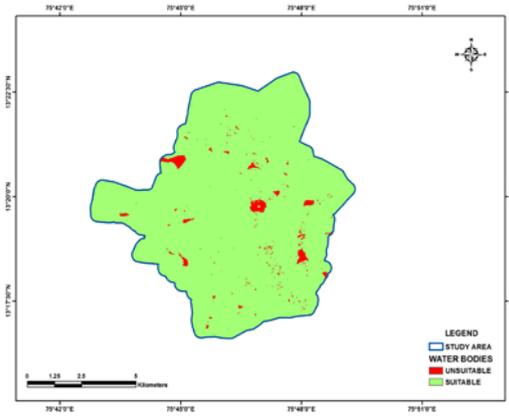


Fig.8 Suitable and unsuitable area on water bodies layer

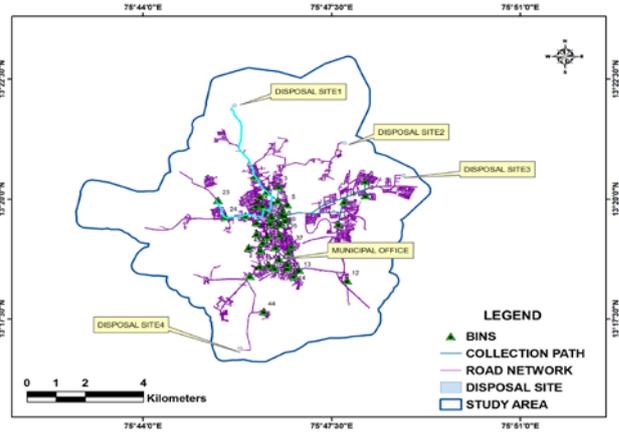


Fig.9 Selected 4 disposal sites and final highly selected disposal site 1

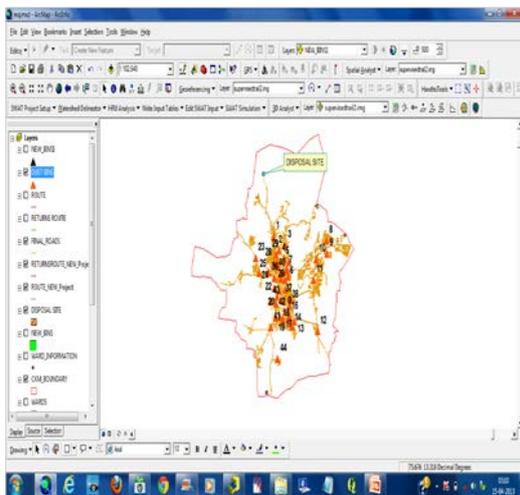


Fig. 10 Map showing final disposal site and 44 containers

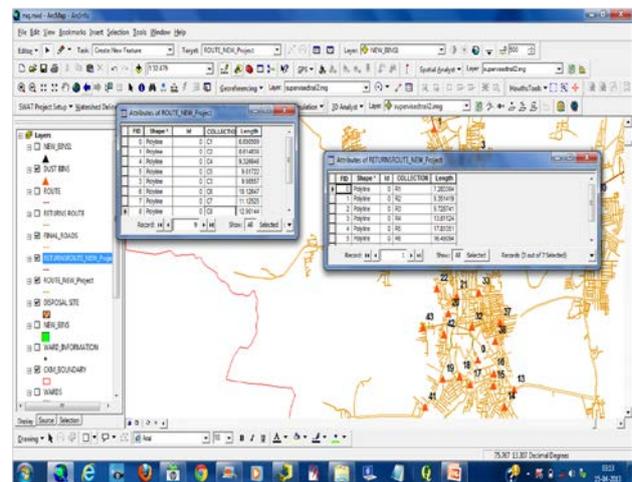


Fig.11 Optimized path for collection of waste from secondary containers to disposal site