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Optimisation of Municipal Solid Waste Management of Indore City using GIS

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ABSTRACT: As a result of rapidly increase in population Municipal solid waste (MSW) management is becoming a hot cake in urban areas. It has become an obligatory function of Municipal Corporation and urban local bodies. Other factors which need almost attention are high rate of Municipal solid waste generation, Complexity of generated waste and last but not the least the scarcity of land. Indore is the largest city and business capital of Madhya Pradesh state. The present population is 24,73027 lakhs. A part from infrastructural development going on for sustainable development MSW management should also be taken care off. However the manual analysis of urban solid waste management is very tedious as it involves a huge data and statists. Hence it demands computerization of system. Geographical Information System is a tool introduced to overcome this limitation and make waste management planning easy efficient and can be implement quickly also. It will reduce the waste management work load to great extent.

The present study aims at Analyzing existing status of generation, collection, storage, transportation, treatment and disposal activities of MSW of Indore city. To Review in detail the present scenario of SWM in Indore city with reference to the MSW Rules, 2000. To propose a GIS based urban solid waste management (SWM) system. To implement the developed model to study area to solve some of the present situation problems like proper allocation of waste bins, optimizing waste transportation routes and planning location of waste disposal facility. This paper portrays Geographical Information System as a decision support tool for Municipal solid waste management. This model will help to get rid of solid waste as per the study area. Amendment in the system through based Geographical Information System model would reduce the waste management workload to some extent and exhibit remedies for some of the Solid waste management problem in the case study area.

Keywords: Municipal solid waste management, Route optimization, Waste collection, GIS, Spatial planning.

I. INTRODUCTION

Economic development, urbanization and improving living standards in cities, have led to increase in the quantity and complexity of generated waste. Urbanization is rapidly increasing in developing countries. In India, proportion of population residing in urban areas has reached 27.8% in 2001. Due to significant growth in urban population, it is estimated that by 2020, 50% of the population will be residing in urban areas (ESCI,2005).Management of Municipal Solid Waste (MSW) resulting out of rapid urbanization has become a serious concern for the government departments, pollution control agencies, regulatory bodies and also public in most of the developing cities.

Cities are expanding awe fully and the issue of Municipal Solid Waste (MSW), is becoming critical due to the increase in quantity and complexity of generated waste and scarcity of land for its disposal. The unmanageable MSW poses various environmental problems such as nuisance from odor, prevalence of unhygienic conditions and ground water pollution etc. Municipal Solid Waste Management is an obligatory function of Municipal Corporation and Urban Local Bodies. This function is included in the 12th schedule appended to the constitution of India through 74th amendment in 1993.

Indore is the largest city and the business capital of Madhya Pradesh. As per 2001 census, Indore is the 17th amongst the 23million cities of India.

Its economic growth has estimated urbanization, but lack of commensurate investment in urban infrastructure and services has resulted in an overall deterioration of urban quality of life.

Indore Municipal Corporation (IMC) is responsible for solid waste management in Indore city. It has a population of 15.42lakhs(as per census 2001), with an area of 130.17km^2.The projected population of 2014 is 26,49684 lakhs. The Municipal Solid Waste generation of Indore Municipal Corporation was 685 tons per day(TPD), out of which only 461 tones per day is collected and transported to dumping ground. This is about a collection efficiency of 67% , IMC uses dumper places as a major waste disposal option. Indore Municipal Corporation has identified a disposal site of Devguradia, 15km away from the city centre of Indore, more than 25years ago, for disposal of Municipal Solid Waste. Till date waste is being dumped in this site and there is no other site available. The existing site of Devguradia has 140 acres of land is planned to be given on lease by IMC to a private operator to set up a waste processing and compost manufacturing facility. The present land available is about 125acres.The large amount of data involved makes manual analysis of solid waste management system highly tedious. Computerization of the systems can help to overcome this limitation. In addition, Optimization can be done effectively in a computerized system to enhance the system efficiency and various options could be analyzed and compared on the basis of economics, efficiency of the services or any other suitable parameter. Presently, computerized systems are extensively used for Municipal services in IMC. Also IMC has undertaken Geographical Information System (GIS), for assessment and collection department. An attempt is made in this project to develop SWM system using GIS for representative zone in the city which can be replicated to other zones in the city. As soon as the GIS system for assessment and collection department comes into force, same infrastructure can be utilized for SWM Department.

SWM GIS may be integrated in system at almost no cost.

II. METHODOLOGY

A. Description of study area

Indore the most prominent city of Madhya Pradesh and the district headquarter of the district is situated on the western part of Malwa (known as Deccan Plateau) on the banks of two small rivers the Khan and the Saraswati. Indore city lies between 22^o 43'N latitude and 76^o 42'E longitude. It is centrally located in the Indore District with an average of 550 meters above MSL. It has an area of about 130.17 km^2 and occupies a relatively flat plateau having a gentle slope towards North. The city has black cotton soil till 5 ft., hard soil till 15 ft., red soils till 30 ft., and rocky terrain.

The climate is typically seasonal with three distinct dry, wet and cold seasons. Average temperature during winter (November to February) will be around 10 C and the recorded lowest is 1.5^o C. During summer (April to June), the days are hot (35^o C to 40^o C) with the peak summer day temperature sometimes reaching 45^o C. Indore receives a moderate rainfall of around 800 mm from southwest monsoon. The population of Indore city increased from 5.73 lacks in the year 1971 to 14.73 lacks in the year 2001.

B. Description of Data collection and Spatial Database

To efficiently manage the municipal solid waste system, detail spatial information is required. This information is related to the geographical background of the area under investigation, as well as to spatial data related to waste collection procedure. It contain study area boundary, population density, satellite image, road network, location capacity time schedule of waste bin.

Table 1. Data collection and their source.

Data	Source
Study area boundary	IMC Corporation
Population Density	Senses 2011
Satellite image	Google earth and ARCGIS
Road network	IMC Corporation and ARCGIS
Location of waste bin	IMC Corporation
Capacities of bin	IMC Corporation
Time schedule for the collection process	IMC Corporation
Existing collection routes	IMC Corporation
Vehicle fuel consumption	IMC Corporation

For the optimization of the collection process a spatial geodatabase was constructed, in a standard commercial GIS environment (ArcGIS). This ensures compatibility with available data from municipality and many network routs.

Table 2. Spatial database- type of data and its geometry.

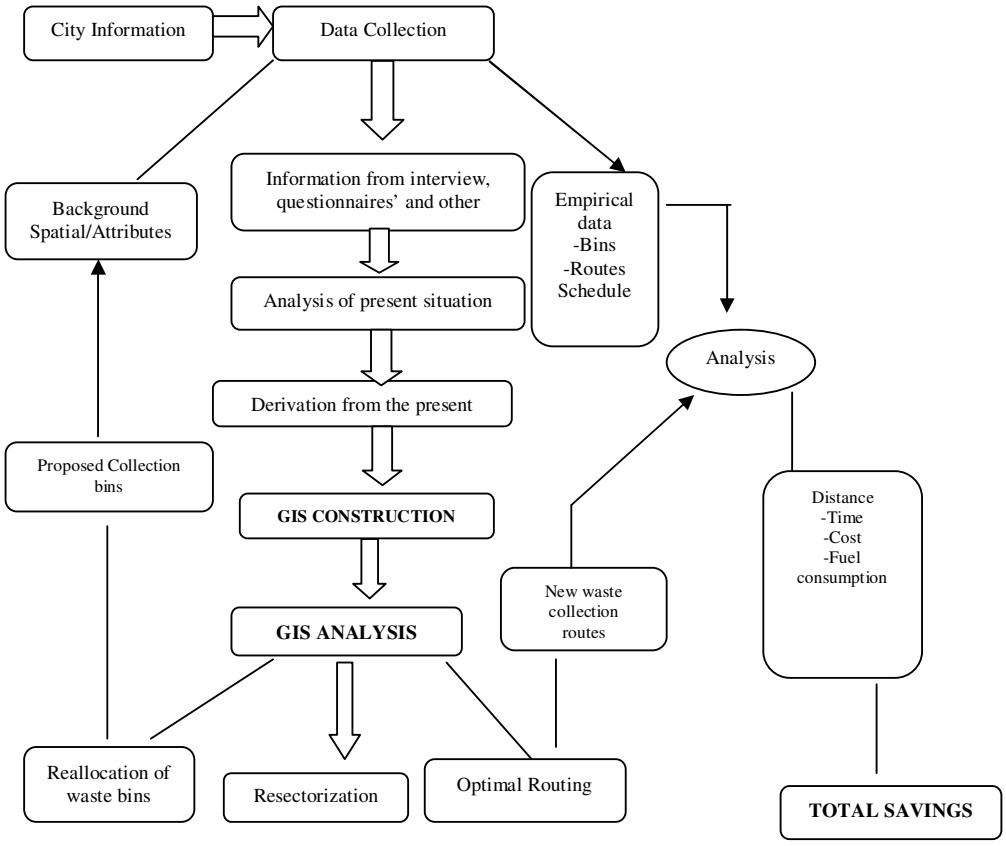
Spatial data	Details	Geometry
Road network	Main road and internal	Line
Present Waste bin	All type of waste bin present	Point
Land use	Residential commercial industrial, slum	Polygon
Open dump	All open dump area	Point

C. Methodology used

GIS provide a powerful context to import, manage and analyses spatially based data. Method is implementing in three steps.

(i) Spatial database of study area.
(ii) Reallocation of waste bins in study area using GIS.
(iii) Optimization of routes, minimum time, and distance.

D. Proposed methodology



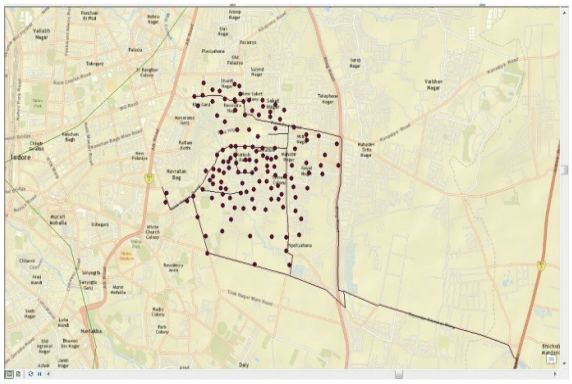
III. RESULTS AND DISCUSSION

From the data base of community bins created in GIS, ward wise list collection points and the type of storage bins used. It is clear that dumper placer contain of size 2.5m3 are most common used for storage of solid waste. There exist open dump at many places. This is due to non placement of community bins at convenient distance.

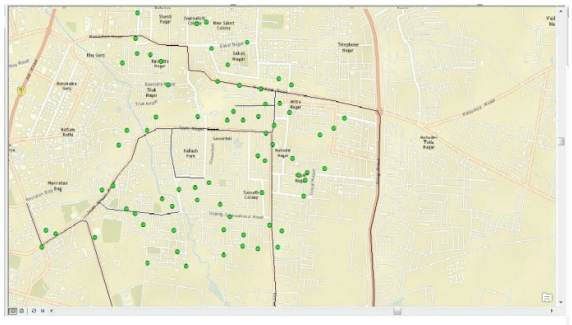
Table 3. Ward wise list of solid waste collection spots and storage bins.

Ward no	Area Km3	Pop_2014	MSW_G_2014 TPD	Qty of 7.5m3 bins	Qty of 2.5m3 bins
44	1.649	23862	12	3	23
45	0.653	24070	11	1	13
47	1.171	24193	11	0	27
49	1.394	23900	12	2	18
	4.867	139753	46	6	81

A. Base map of waste bin present in study area



B. Reallocation of waste bins in study area



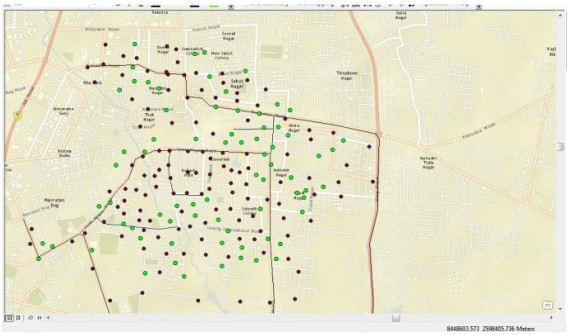
With the help of GIS and field survey this map is taken showing the number of bins with is needed to be allocate in the study area.

C . Present and Reallocated bins in study area

This base shows the number of bins with is present in study area and the number of bins needed to be placed in study area.

D. Base map of IMC showing optimal routing of transport system

The transportation cost in existing scenario without transfer station and sane after commissioning of transfer station is presented. The result of the analysis is made on the available data and compared with expenditure. This help as a decision support in planning the transfer station facility.



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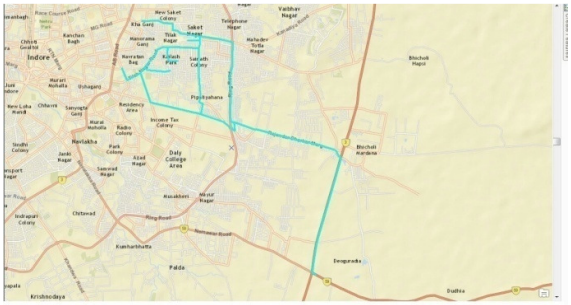

Table 4. Saving in waste transportation cost by planning additional waste disposal facilit*y.*

Zone No	NAME	Route Length H Km	MSW_G_ 2014*	Present Scenario	Proposed Scenario	Improvement
6	Route_06	11.78	47	5.857	7.21	1.3560
7	Route_09	10.18	44	4.740	5.84	1.0973
8	Route_07	11.71	42	5.205	6.41	1.2052
9	Route_08	10.78	43	4.907	6.04	1.1361
10	Route_10	6.74	48	3.425	4.22	0.7930
11	Route_11	8.04	60	5.107	6.29	1.1825
12	Route_12	10.18	56	6.033	7.43	1.3969
13	Route_13	11.78	51	6.355	7.83	1.4713
1	Route_01	14.86	52	8.175	10.07	1.8928
2	Route_02	12.27	53	6.880	8.47	1.5929
3	Route_03	12.83	54	7.331	9.03	1.6973
4	Route_04	15.18	53	8.515	10.49	1.9715
5	Route_05	15.03	45	7.159	8.82	1.6574
14	Route_14	17.52	57	10.568	13.03	2.4469
15	Route_15	18.46	51	9.963	12.27	2.3067
	Total	187.35	756	Total improvement		23.2039
	Avg.route length	12.49				

Group I Avg. route length = 10 15 with proposed scenario
Group II Avg. route length = 10 15 with proposed scenario
*Assuming Group II contributing new disposal site and Avg. route length is same as that of Group I

E. Cost benefits analysis with additional disposal facility

Large portion of funds allocated for waste management is used for collection element of municipal solid waste may account for more than 70% of the total management budget. It is therefore crucial to optimize for waste collection and transportation.

Zone of the city are divided into two groups, Group I include the zone that has waste collection route length less than 12km and other is Group II. Effective transportation for individual zone is calculated using general mathematics for present scenario, assuming all the waste generated is collected and transported 100%. Then assuming there exist another waste disposal site and zone in Group II contribute waste to the facility. The average roué length of Group II with new disposal facility is assumed same as that of group I with existing disposal facility. Zone in Group I are allocated to disposal facility at Devaguradia and Group II zones, allocated tp proposed disposal facility. Effective transportation for individual zones in Group I Group II is then recalculated in proposed situation. The average route length in proposed scenario come out to 12.5 km where as in proposed scenario it will be 10.5. then effective transportation for each zone is calculated for both the scenario. From the analysis It is found that there will be 23.3% of net saving in waste transportation.

F. Saving in waste transportation cost by planning additional waste disposal Facility

In year 2013-2014, out of its local budget provision Rs 867 lakhs IMC has spent about Rs 425 lakhs only on transportation of MSW. The collection efficiency was 58% only. With the help of modern information technology like GIS planning and optimization of waste collection and transportation can be possible.

Table 5. MSW collected and Transported to Dumping Ground in year 2013-14.

MSW Collection and Transported to Dumping Ground in year 2013-14			Collection efficiency
Month	Waste collection in tons	MSW collected/day	
Apr -13	8767.88	292.3	
May -13	9669.13	311.9	
June -13	11283.21	376.1	
July -13	12454.98	401.8	
Aug -13	15274	492.7	
Sep-13	16706	556.9	
Oct-13	16402	529.1	
Nov-13	14635	487.8	
Dec-13	17104	551.7	
Jan -14	16115	519.8	=waste transported to dumping site/waste generated
Feb-14	14681	524.3	
Marc -14	15271.39	492.6	=461*100/800*
	168363.59	461.3	=58%

Source : IMC and weigh bridge (Prabhu Tolkata, nemavar road, Indore). The waste generation for year 2014 was estimated to 800 TPD*

G. Discussion of transfer station cost analysis

Devaguradia, the disposal site of IMC is more than 15km. away from the city core area. Sending the entire vehicle to tenching ground proves to be economical. At present IMC do not have any transfer stations. IMC has planned to build two transfer station one at Kabitkhedi and other at Dhar Kothi to economized and smoothen the waste transportation up to the disposal facility. Well designed transfer station with transferring mechanism constructed to facilitate unloading of waste or dumper places container. Waste will be automatically in large hauling truck at transfer station and will be sent to waste processing facility. The transfer station cost analysis show that there is saving in transportation cost.

With present scenario through the saving is marginal but in long term with increase in fuel cost and MSW load the saving will be substantial. 27 long hauling vehicles which are at present not in use, can be utilized for transporting waste from transfer station to devaguradia disposal site. The proposed transfer stations are not located on the basis of waste generation and transportation distance as seen from city map.

H. Discussion of bins allocation

The model proposed in this paper was design for planning the allocation of waste bins in the case study area. There are several aspect taken into consideration in planning the waste management by evaluating the bins allocation first was to analyze the location of existing waste bins in the area. The planning concern was to verify the convenience and insolvencies users due to close proximity of the bins to sensitive land use. The planning of waste bin allocation can further extend for segregation of waste in two categories and for this provision of recyclable bin can be evaluated. This requires detail land use data which will be available on completion of IMCs GIS project. The proposal will be intended to provide the recyclable waste collection bin to those areas with generate recyclable waste.

The analysis showed the required results which are useful for relocating the existing bins and for locating the new ones for a refined waste management system. The proposal is cost effective with the consideration of the budget constraint of the system while planning the waste management system. Situation based planning is carried to make the consideration of the data available and situational constrains. Sometime it is not fissile to place a waste bin in particular area due to narrow lane and congested area like slum or road side of high traffic density road or may be due to sensitive area like religious place etc. house to house collection is thus the best option for majority of MSWM problems. With rigorous public awareness program, awareness campaign through school and involvement of local NGOs and implementation of house to house collection in phases is necessary.

IV. CONCLUSION

The paper presentation states an efficient designing and developing of a proper storage, collection and disposal system plan for Indore municipal corporation (Madhya Pradesh) India. A GIS optimal routing model has been developed by considering the parameter like population density, waste generation capacity, road network and types of road, storage bins and collection vehicle etc. This model helps to find minimum cost/distance efficient collection pattern for transportation of solid waste to landfill.

Indore Municipal Corporation can use this model as decision support tool for efficient management of moving the solid waste, fuel consumption and work schedule for the worker and vehicle in daily route of life.

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