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Enhancing Municipal Solid Waste Management in Durg City Using Geographical Information System Techniques

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Abstract: The rapid urbanization, expanding population, limited funding, emerging constraints on energy and raw materials, and growing industrial, commercial, and socio-economic development pose challenges for a city like Durg. The Durg city area has experienced a surge in the production of several forms of garbage. The management of solid waste is a significant challenge encountered by the city of Durg. Maintaining daily logs of collection and transport of solid trash in the city of Durg is a laborious and challenging task due to the huge amount of field data and statistics involved. Currently, 80% of the entire expenditure for solid waste management is allocated towards the collection and transportation processes. Therefore, it is imperative to implement effective monitoring of the system. This article aims to assess the proposed placement of municipal bins and the many alternative routes used for solid waste collection in the city of Durg. Utilizing Arc GIS 10, a geographical information system (GIS) centered urban municipal solid waste (MSW) management system is suggested for the designated region. This system aims to enhance the efficiency of trash collection and transportation routes by optimizing them and reallocating garbage bins. The objective is to minimize the distance traveled and time taken for waste management operations. Therefore, using a Geographical Information System model would somewhat alleviate the complexities in the waste management system and provide solutions for the same in the study area.

Keyword– *MSW Management, GIS Software, Cost Optimization*

INTRODUCTION

Addressing waste management practices in Durg requires leveraging Geographic Information System (GIS) technology to effectively track and manage solid waste. By implementing GIS, we can optimize waste collection routes, identify areas with high waste generation, and plan for efficient disposal sites. As society and industry continue to grow, the volume of solid waste generated has significantly increased. Urban population growth has Ruther exacerbated this issue, leading to a considerable rise in waste production.Urban areas produce substantial amounts of solid waste daily, originating from households, hospitals, industries, agricultural fields, and market centers. The traditional methods of collecting, handling, and disposing of this waste have become increasingly challenging. Our research highlights the significant costs associated with municipal solid waste collection and transportation, which can account for up to 70-100% of total waste management expenses.Advanced geotechnology, such as GIS, can address the placement of both existing and new collection bins. GIS has proven highly effective in various applications, including urban planning, transportation planning, natural resource management, health sciences, forestry, geology, disaster prevention, and environmental modeling. Specifically, in waste management, GIS helps in siting waste facilities and optimizing waste collection and transportation routes—a field of interest since the early days of GIS technology.Efficient waste collection remains a challenge, with the primary goal being to optimize vehicle routes to minimize travel costs, such as distance and time. The success of these decision-making tools depends on the accuracy and amount of information available to decision-makers. Recently, the use of GIS software modeling tools as support systems has grown, facilitating the collection of large quantities of waste and geo-spatial information.

In Durg, the methodology was applied using real field data. Key aspects included analyzing the current status of MSW collection bins and their locations across different zones of

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the city. The following steps were proposed to enhance waste collection and transportation routes:

Optimize waste collection routes using Arc GIS 10s Network Analyst, considering criteria like minimum time and distance.

Determine new locations for waste collection community bins through field surveys and reschedule waste collection routes using GIS routing optimization.

1. Evaluate the proposed methods based on the time and distance involved.
2. Assess the benefits of these approaches by measuring the amount of waste collected and transported, aiming to reduce collection time and travel distance.
3. Implementing these strategies will significantly improve waste management efficiency in Durg, addressing the challenges posed by increasing waste generation.

City Analysis

Figure 1: Different Wards of Durg city Municipal Corporation

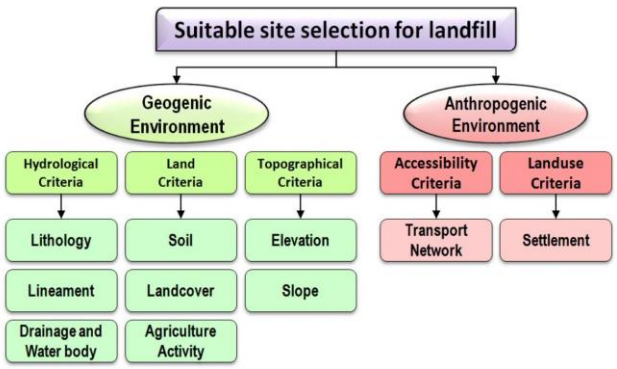

Figure 1: Tree diagram of the decision process developed for selection of suitable landfill sites

City Profile

Durg is a prominent city located in the central portion of India, namely in the Chhattisgarh state. It is situated to the east of the Seonath River, also known as the Shivnath River. Durg is an integral part of the Durg-Bhilai urban agglomeration [20]. Durg city is a prominent agricultural market that specializes in the processing of rice and pigeon peas. The city of Durg gained significance as a prominent industrial center following the building of a major steel factory in Bhilai. Additional sectors encompass brass craftsmanship and bell-metal craftsmanship, oil extraction, mining, and textile production. The headquarters of Durg District, which is the third largest district in Chhattisgarh, is located here. The Durg municipal corporation was previously organized into a total of 60 wards. The current study has selected the Durg City Municipal Corporation to effectively manage municipal solid waste (MSW)[16].

Table 1: Details of Ward

S.N.	Name ofWard	Population	Area Sq.Km.
1	Nayapara	7547	1.5000
2	RajivNagar	4923	0.3260
3	Mathpara(North)	4161	0.1089
4	Mathpara(South)	3136	0.1073
5	Mararpara	4018	0.2344
6	ThethvarPara	2919	0.0515
7	KillaMandir	3417	0.1019
8	TakiyaPara	5091	0.1350
9	SwamiVivekanand	4595	0.2730
10	ShankarNagar (West)	4746	0.1213
11	ShankarNagar (East)	4525	0.1950
12	MohanNagar (West)	4486	0.1450
13	MohanNagar (East)	4459	0.3556
14	Sikola Bhatha	4192	0.1492
15	Sikola Basti(South)	4645	1.2710
16	Sikola Basti(North)	6078	1.2460
17	AudhogikNagar(North)	4891	0.9294
18	AudhogikNagar(South)	6089	0.4880
S.N.	**Name ofWard**	**Population**	**Area Sq.Km.**

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19	Shahid BhagatSingh(South)	6599	0.0610
20	Shahid BhagatSingh(North)	3003	0.2413
21	Titurdih	5352	0.2942
22	StationPara	3581	0.4288
23	DeepakNagar	4165	0.3688
24	AmdiMandir	4582	0.2488
25	GayatriMandir	3390	0.1249
26	Santrabadi	4002	0.1246
27	PolsayaPara	4118	0.0910
28	Pachri Para	3481	0.1123
29	AsaptalWard	2581	0.8743
30	TamerPara	2747	0.1413
31	Aapapura	2918	0.1225
32	BramhanPara	3915	0.1135
33	Chandi Mandir	3873	0.1159

DATACOLLECTIONANDDESCRIPTION

Effective administration of the municipal solid waste collection and transportation system relies heavily on detailed spatial information. This includes both the geographical context of the study area and the spatial data related to the waste collection and transportation processes.

In Durg City, the Municipal Corporation has compiled an extensive database for waste management. This database includes statistical analyses of various factors such as population, waste generation, types and locations of waste bins, road networks, traffic patterns, current collection vehicle routes, and geographic boundaries. To determine the optimal placement of waste bins and to optimize collection and transportation routes for the new locations, the following data (sourced from [4]) were created:

1. Study Area Boundary: Defined limits of the study area within the Durg Corporation.
2. Land Use: Classification and utilization of land within the study area, depicted on a toposheet.
3. Satellite Imagery: Aerial photographs or images of the study area obtained from Google Earth.
4. Road Network: Depiction of the road network within the study area on a toposheet.
5. Road Classification: Information regarding the classification of roads based on official toposheet plans, Durg Corporation data, and field work.
6. Current Bin Placement: Locations and capacities of rubbish bins in the Durg Corporation area, along with the collection process time schedule, all sourced from Durg Corporation and field work.
7. Proposed Bin Placement: Suggested locations for new rubbish bins based on field work within the Durg Corporation area.

The project involves optimizing a total of 164 waste collection routes, referred to as Collection Routes (CR), across the Durg Corporation region. Each route, including CR1, is selected for optimization using GIS technology. The project entailed designing and implementing a spatial geodatabase with commercial GIS software, specifically ESRIs ArcGIS 10. The necessary spatial data, provided by the Durg City Municipal Corporation, includes road networks, current routes, bin locations, and geographic borders. This data was further updated through field work and supplemented with non-spatial data such as road length, name, type, width, average vehicle speed, journey time, bin number, type, capacity, and collection times.

Additionally, the spatial characteristics of the road network were recorded, encompassing traffic regulations, signage, and specific limitations (e.g., turn restrictions), to accurately represent the actual conditions of the road network..

METHODOLOGY

4.1 Spatial Database Development:

In order to optimize the garbage collection system, a spatial database (SDB) was created within Geographic Information System (GIS) framework to analyze the spatial data. The main sources for the SDB comprise

(a) Topographic map

(b) Maps converted into digital format using Autodesk 2014 software The data provided is obtained via on-site research.

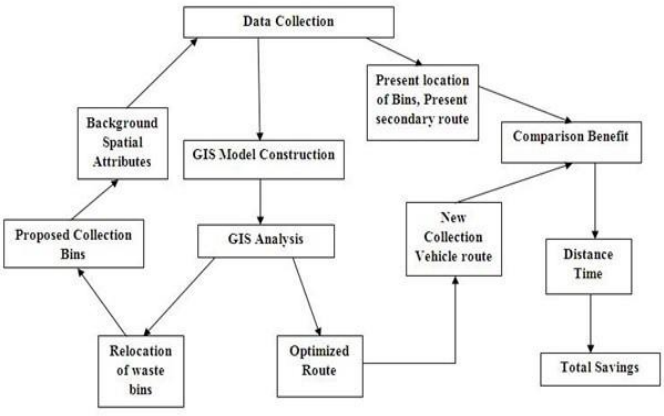

Figure 2:Proposed Methodology

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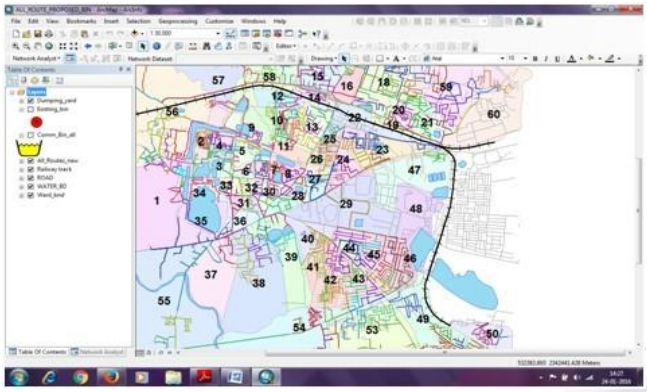

Figure 3:Road Networks of Durg Corporation

4.2 Reallocation of waste collection bins

In the subsequent stage of our process, we will reallocate waste pickup bins as required. This procedure is conducted within a Geographic Information System (GIS) setting, utilizing sophisticated spatial analysis features. The repositioning of garbage collection bins is determined by the following criteria: Field Study and Data Collection: Utilize information gathered from field studies and the Durg Corporation to ascertain the quantity of bins currently in existence.

Rules for reallocating resources:

Position receptacles in any location where uncovered waste disposal sites are detected.Place bins strategically around the road network, prioritizing intersections. Deploy more receptacles in close proximity to the current bin placements.

Permit the installation of multiple waste receptacles at a single intersection, based on the surrounding land utilization and population density. This reallocation guarantees that garbage collection bins are properly positioned to optimize efficiency and coverage.

4.3 Routing-Network Analysis

Arc GIS 10 Network Analyst modeling is used to optimize waste collection routes. This model incorporates real-world transportation constraints such as one-way roads, prohibited turns (e.g., U-turns), and the need for transportation at intersections (nodes) and along roadways. These nodes represent locations where vehicles stop to collect waste bins. The total travel time for the most efficient route is calculated by adding the travel time for each road segment to the time required for waste pickup at each bin. The result is an optimal solution based on both distance and time criteria. This approach ensures the route optimization is practical and efficient, considering actual transportation data.

RESULTS AND DISCUSSION

The developed GIS model was used to optimize collection routes CR1 to CR164. This method was applied to analyze the garbage collection strategy for Zone A of the Durg City Municipal Corporation area. Two distinct optimization methodologies were considered:

The established GIS model was used to optimize collection routes CR1 to CR164.

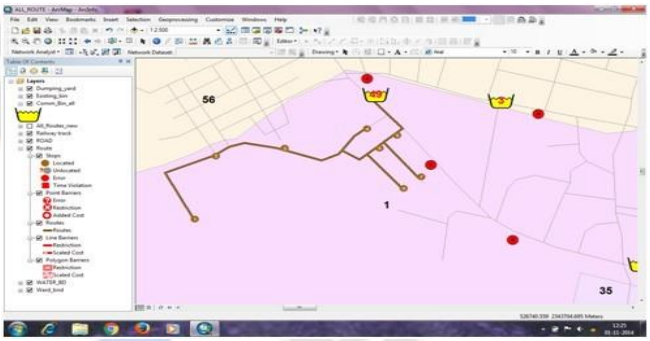

Figure 4: Present Collection Route_01

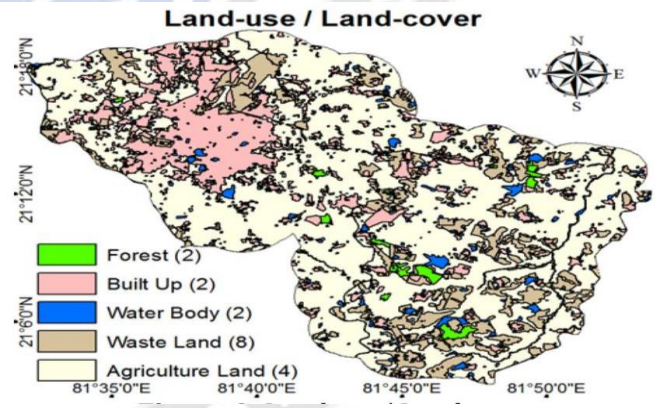

Figure 5:Land-use/Land-cover

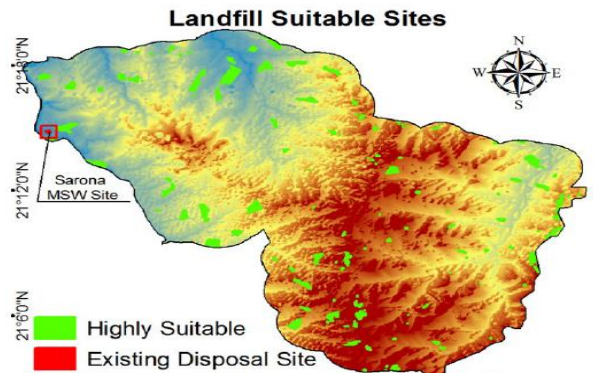

Figure 6: Positive Window Area for Proposed Landfill Sites

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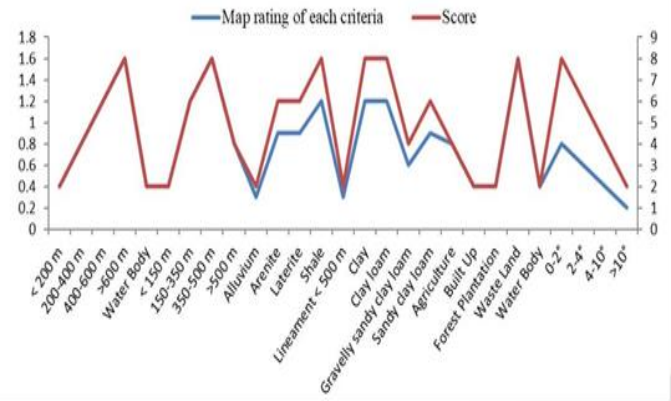

Figure 7:Trend graph depicting the appropriateness of land based on a single criterion for overlay analysis

CONCLUSION

Optimization of collection routes CR1 to CR 164 by the developed by GIS model. The project utilized GIS technology to create a methodology for redistributing garbage bins in Zone A and improving the collection and transportation routes for municipal solid waste (MSW). The approach employs diverse geographical data, including the road network, garbage bin locations, and land use, in combination with sophisticated spatial analysis Geographic Information System (GIS) tools. The results suggest that the best scenario is more efficient in terms of both collection and transportation time, as well as the distance traveled. The objective of the project is to create an effective and well-organized strategy for the storage, collection, and disposal of waste for the Durg City Municipal Corporation in India. A Geographic Information System (GIS) was used to create an efficient routing model. This model took into account several factors such as population density, trash generation capacity, road network, and transportation routes. This model facilitates the calculation of the optimal cost and distance required for the efficient collection and transportation of solid waste. The Durg City Municipal Corporation can utilize this model as a decision support tool for effectively managing the movement of solid waste, optimizing fuel consumption, and scheduling the activity of workers and vehicles in their daily routes.

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