GEO-EYE

ORIGINAL ARTICLE

A GIS-Based Assessment of the Status and Challenges of Solid Waste Management in Kalaburagi City, Karnataka, India

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Abstract

Rapid urbanisation and the increasing waste generation put significant pressure on Solid Waste Management (SWM) systems in medium-sized Indian cities, such as Kalaburagi. This research will undertake a GIS-based assessment of the present state of the SWM in Kalaburagi city with a focus on the spatial performance. Field data collected using Global Positioning System (GPS) and imagery from Google Earth will provide data that can be used to map the spatial distribution of community bin locations, identify unauthorised dumping sites, analyse the route taken by vehicles transporting waste and assess the suitability of the current landfill site. Spatial data analysis has shown that there are unequal distributions of community bins across the city with a concentration of community bins along road networks in commercial areas of the city and nearly no community bins located in residential areas of the city. There have been over 1432 identified unauthorised dumpsite locations, primarily along roads and vacant plots of land in high-density residential areas of the city, indicating inefficient door-to-door (D2D) collections and a lack of awareness among residents as to the location of authorised waste disposal facilities. Analysis of the route taken by vehicles collecting waste indicates unplanned movements of these vehicles resulting in overlapping operations and increased operating costs. Spatial assessments indicate that the current landfill site is environmentally unsuitable due to its proximity to water bodies and lacks sufficient space to expand the site's capacity in the future. Overall, this study demonstrates spatial shortcomings in the SWM system currently in operation within the city and serves as a baseline for future GIS-based planning and optimisation of the SWM system.

Keywords: Geographical Information System (GIS); Global Positioning System (GPS); Landfill Analysis; Solid Waste Management (SWM); Spatial Assessment; Unauthorised Dumpsites

1 Introduction

Garbage or trash are the definitions of "solid waste", which consists of different kinds of materials [1], thus forming a mix of heterogeneity. In terms of quantity and type of solid waste, it varies greatly from one area to another [2, 3]. Developing countries such as India produce large amounts of trash daily which takes up a lot of space and causes environmental issues [4, 5]. Therefore, proper handling of the generated trash is an enormous problem for many Urban Local Bodies (ULB) in India [6].

Solid Waste Management (SWM) is a major component of developing the city sustainably, therefore it includes all the steps of collecting, segregating, storing, transporting, processing, and disposing of solid waste to minimise their negative impacts on the environment [7, 8]. The rapid expansion of urbanisation, industrialisation, and economic activities has resulted in an increase in the generation of solid waste [9]. Although there has been a significant improvement in the social, economic, and environmental aspects of India, the SWM has encountered considerable problems, particularly in large population cities [10, 11].

Therefore, it is essential to develop and implement advanced technologies for managing SWM to mitigate the negative effects on public health and the environment [12, 13]. GIS could be employed to efficiently manage solid waste in cities [14]. GIS facilitates visualisation and mapping of waste management infrastructures, improves waste collection and transportation routes, and evaluates the suitability of sites for landfill through the incorporation of both spatial and non-spatial data [15]. GIS also helps to develop suitable policies to reduce the total volume of waste through spatial analysis [16].

Like other medium-sized cities in India, Kalaburagi City generates substantial waste from both residential and non-residential areas. The city corporation is responsible for managing the solid waste generated in the city, including collecting, transporting, disposing of, and performing other related processes for the collected waste. As part of innovative practices in the city's SWM system, the community bins were removed entirely from the city in 2022, and door-to-door (D2D) waste collection was implemented to collect waste from residential and non-residential sources directly. To collect waste from floating populations, small-round stainless-steel community bins are placed at 94 locations throughout the city, each with a capacity of 1.1 m^3, in commercial areas and along major roads [17].

Achieving the complete collection, processing, and disposal of solid waste remains unattainable in many cities due to various challenges [18], a phenomenon also observed in Kalaburagi. The Annual Solid Waste Management Report, 2024, of Kalaburagi states that approximately 20 per cent of the total waste generated in the city is not collected from its source. These uncollected wastes are unauthorizedly dumped along the roads or on vacant land. Thus, the present study was conducted to understand the effectiveness of D2D waste collection from the sources, including the efficiency of the present vehicle routes for waste collection and the locational suitability of the landfill site.

2 Study area

Kalaburagi city is recognised as a significant commercial and industrial centre within the Hyderabad-Karnataka region [19], located approximately 637 km from Bengaluru, the state's capital. The city is geographically located between 17°17′ and 17°23′ North latitude and 76°47′ and 76°53′ East Longitude [20], as shown in [Fig. 1]. The city's population is 543,147 [21], and it is estimated at 734,837 for 2024, based on an exponential growth formula. The population is spread over 64.48 Sq. Km in 55 wards. The city serves as the administrative capital of the Kalaburagi District. The city has 1,15,696 households and 16,632 non-residential buildings [17].

The topography of Kalaburagi city is relatively flat, with gently undulating terrain in the northern and eastern parts. The city is located on the Deccan Plateau and is mostly composed of Deccan Traps, characterised by rocky hill formations, residual hills, and large expanses of flat, open plains [22]. All of the city is covered in the same type of black rock, and therefore, all of it retains more heat than other areas that do not have this same type of rock formation. The city is completely built on top of fertile black clays. The city's average elevation is 454.57 meters above mean sea level. The city is built around the natural lake called Sharanabasaveshwara, which is the lowest point and also serves as a reservoir for water run-off from surrounding areas. The city has a semi-arid climate, characterised by very hot summers, moderate rainfall during the monsoon season and mild winters [23].

Kalaburagi city is governed by the Kalaburagi Mahanagara Palike (KMP), also known as the Kalaburagi Municipal Corporation (KMC), the ULB responsible for managing the city's civic systems and services, including SWM. The Environmental Engineer (EE) is responsible for the various environmental functions, including sanitation of the city. KMP has deployed three EEs to manage SWM activities, supported by Junior Environment Engineers and Senior and Junior Health Inspectors.

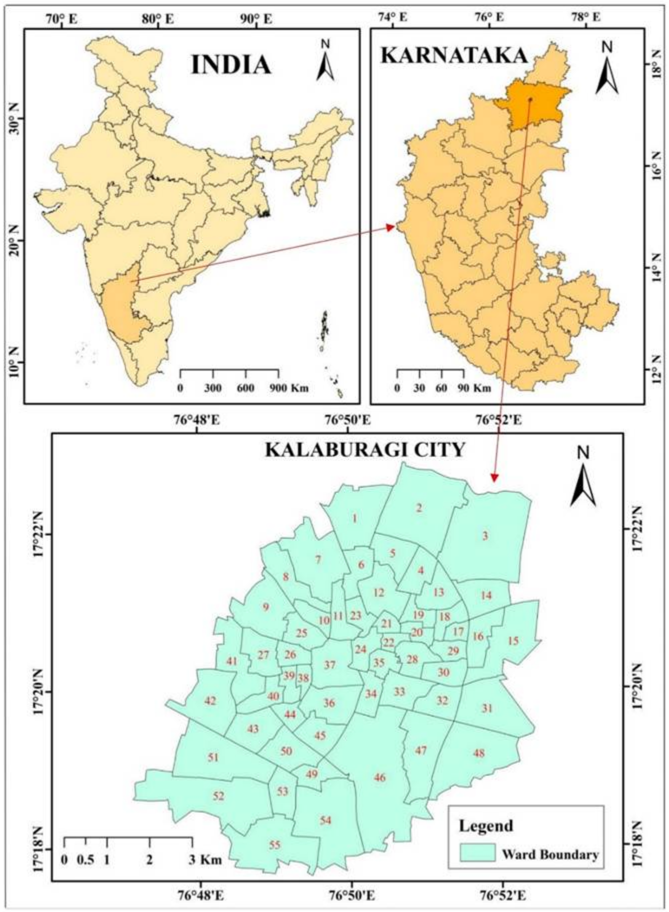

Fig. 1: Location Map of Kalaburagi City

3 Materials and Methods

The location of illegal dumping sites and community bins, which are installed in the city for the collection of waste from the floating population, was collected through a field survey using the 'GPS Waypoints' mobile application to identify the status of waste collection at the source. To understand the current transportation status of solid waste by various vehicles in the city, the route information for each vehicle was collected from the logbook provided by KMP, and the city's complete road network was manually digitised from Google Earth's recent satellite imagery. The present landfill site and its surrounding land use and land cover were also digitised from Google Earth imagery to evaluate site suitability.

4 Results

4.1 Unauthorised dumping sites

Unauthorised dumping sites are the throwing or dumping of waste on streets, roads or vacant plots without proper disposal [24]. It is also known as illegal dump sites [25] or open dumping sites [26]. A total of 1,432 unauthorised solid waste dumping sites were identified and mapped across the city, regardless of whether they are in residential or non-residential areas. These places are mainly located along roads or at street corners on vacant land, as shown in [Fig. 2]. To determine where the most unauthorised dumping occurs, a Kernel Density Assessment was performed to find out which of the wards had the greatest amount of unauthorised dumping. The greatest rates of unauthorised dumping were found to be in the Wards located in the centre and west of the city, specifically, Wards 6, 12, 23, 24, 25, 26, and 27. Lower rates of unauthorised dumping were located in the adjacent Wards (11, 29, 32, 43, 51, 53, and 54), indicating that there is a slight decrease in the use of unauthorised dumping for waste disposal from the centre of the City. The city's outer regions, particularly wards 2, 3, 14, 15, 31, 48, and 42, exhibit significantly lower or negligible levels of unauthorised dumping, due to lower urban density.

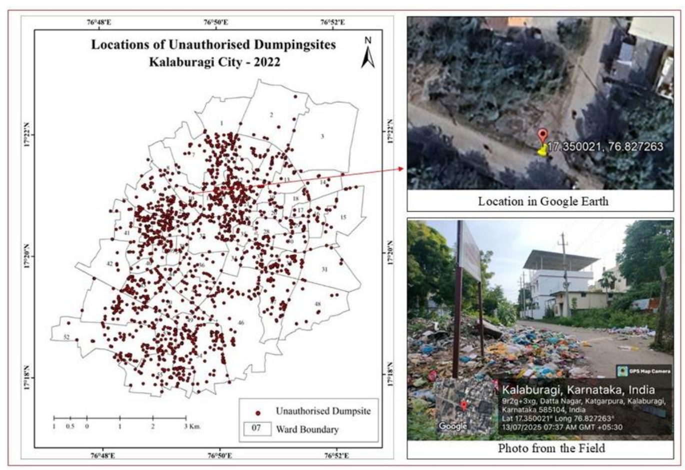

Fig. 2: Map showing the locations of unauthorised dumping sites

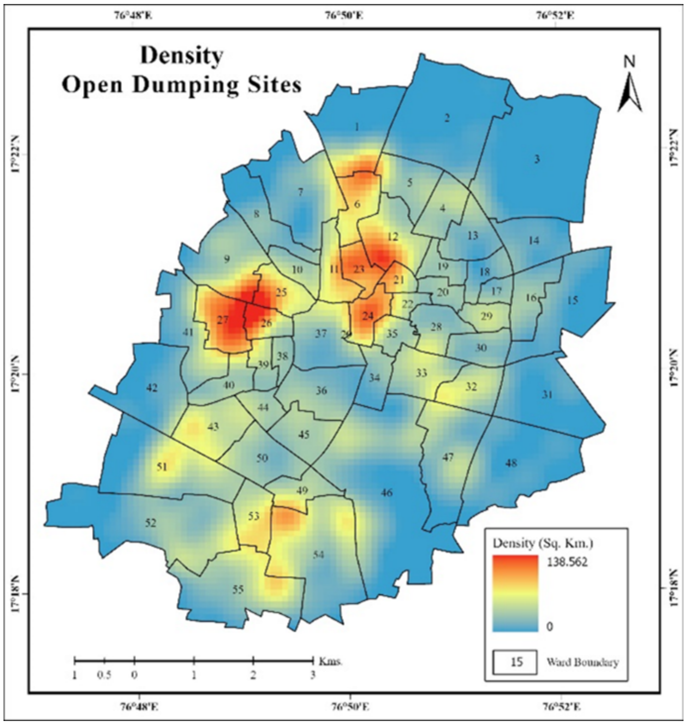

Fig. 3: Map showing the kernel density of open dumping sites

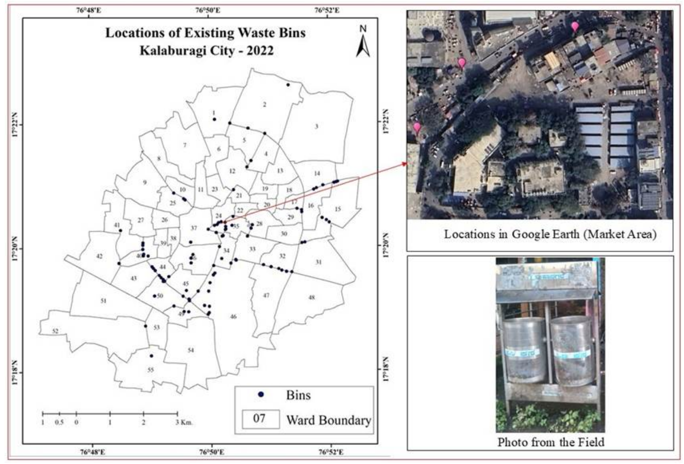

Fig. 4: Map showing the locations of existing Small Community Bins

The higher rate of unauthorised dumpsites is due to inefficiencies in D2D solid waste collection in these areas. These inefficiencies are attributed to poor civic sense, negligence, and a reluctant mindset among both the public and waste-collecting staff. In some areas, Waste collection vehicles cannot go due to streets being blocked or congested by parked vehicles. Another reason is that some vehicles are not collecting because their capacity is already filled, and as a result, they fail to arrive on time. In some areas, people do not hand over waste to the collection vehicles; instead, they throw it out or dispose of it on the streets.

4.2 Status of Community Bins

94 small community bins have been identified and mapped, as shown in [Fig. 4]. The ward-wise assessment revealed that these bins are unevenly distributed across the roads. These small bins are placed along major roads in commercial and market areas for the city's floating population. Wards 15, 24, 35, 44, and 46 have a higher concentration of these small bins. 25 wards have a moderate concentration of bins, while the remaining 25 have none. Many of these bins are damaged, uncovered, or poorly maintained, limiting their utility and accessibility and leading to unpleasant odours and public health issues.

4.3 Waste Collection Route Analysis

Collection of waste is crucial in the SWM system, as it enables the efficient transfer of waste collected from various sources to processing or disposal facilities. The problems associated with fleet capability, route optimisation, and managing operations, along with congested streets, poor roads, and excessive traffic volume, contribute to the inefficiencies associated with waste transportation [27, 28]. The absence of a dynamic, data-driven strategy results in inefficient fleet utilisation and increased operational expenses [29].

According to the Annual Solid Waste Management Report, 2024, of KMP, out of 247.35 tonnes of solid waste produced, 198 tonnes (80%) are transported daily from the city to the landfill site at Udnoor. Solid waste is collected daily in the city using various small vehicles, including Auto-Tippers, Boleros, Tata Aces, and Tata Intras, through the D2D method from both residential and non-residential areas. These collected wastes are transported to larger compactors at 10 locations in the city, then taken to the landfill site.

Tractors are used to collect street sweeping waste and transport it directly to the final landfill site. Waste generated from hospitals (non-hazardous) and market centres is directly transported to the landfill site by Tata Tippers. Parisara Associates and Enviro Biotec Agencies are authorised to collect and dispose of biomedical (hazardous) waste from the city. Manual route planning lacks spatial optimisation; thus, D2D vehicles need to travel longer distances or the same routes unnecessarily. This leads to higher fuel consumption, longer travel times, and larger maintenance costs, resulting in an unnecessary financial burden on KMP. Some D2D vehicles may be overloaded, while others are underutilised; however, they can also be observed without scientific routing. In the absence of GIS, an accurate estimation of route time, considering road conditions and traffic patterns, is not possible, resulting in irregular collection schedules and service delays, which further lead to unauthorised open dumping on streets, a serious issue in the city. In many cases, vehicles are travelling on routes not designed for the new residential area, resulting in inadequate services to many locations.

An analysis was conducted utilising ArcGIS Network Analyst with the current routes for these 168 vehicles to assess the effectiveness of the current routes [Table. 1]. The results showed that several vehicles were providing the same services in many places unnecessarily. Areas where the vehicles were also showing operational overlap included Ambedkar Asaray Colony and Suvarna Nagar, the central bus station and the CIB colony, Taj Nagar and Kakade Chowk, and Shanti Nagar and PWD quarters [Fig. 5].

Table 1: Details of vehicles used for D2D waste collection in Kalaburagi City

Sl. No.	Type	No.
1	Auto Tipper	36
2	Bolero	68
3	Tata Ace	34
4	Tata Intra	30
	Total	**168**

Source: Kalaburagi Mahanagara Palike, 2024

At present, all routes are developed on a manual basis with no optimisation involved. This is leading to unnecessary overlap in the geographic area covered, wasted fuel, and slower delivery of services to residents. In addition, the routes followed by the vehicles do not allow them to enter all residential areas; therefore, there are many areas receiving inadequate or no service. Therefore, through the use of GIS technology, it will be possible to determine the most efficient and shortest route for each vehicle overlapping areas by determining the shortest and most efficient route for each vehicle, taking into account its loading capacity.

Additionally, during interviews with KMP drivers, the drivers identified additional difficulties experienced while operating in the urban area, such as narrow streets, blocked roads caused by parked cars, and inaccurate route maps. All of the above factors further restrict the ability of the vehicles to access the high-density populations of the urban area. These findings highlight the need for an integrated GIS-based routing system, supported by real-time GPS tracking, to enhance transportation efficiency and reduce operational costs.

Fig. 5: Overlapping Routes in D2D Waste Collection

4.4 Landfill Site Evaluation

Finally, the last stage of the SWM is the appropriate and environmentally friendly way that solid waste can be disposed of safely. A scientific method for disposing of waste involves many phases, such as segregation at a source, composting, recycling and placing waste into sanitary landfills [30]. Lack of suitable infrastructures or facilities could potentially affect one of the stages and result in improper waste disposal [31].

The landfill site is located just outside the city and began operating at Udnoor Village in 2006. It is located approximately 7.5 km in aerial distance and 10 km by road from the city centre [32]. It spans a total area of 28 acres and 19 guntas, out of which about 20 acres have already been utilised for waste disposal [33]. It is located 750 meters away from the nearest settlement, ensuring minimal direct health impact from odours and emissions. It is located 3 km from the national highway (NH-150) and 7.5 km from the historical monument Gulbarga Fort [Fig. 6].

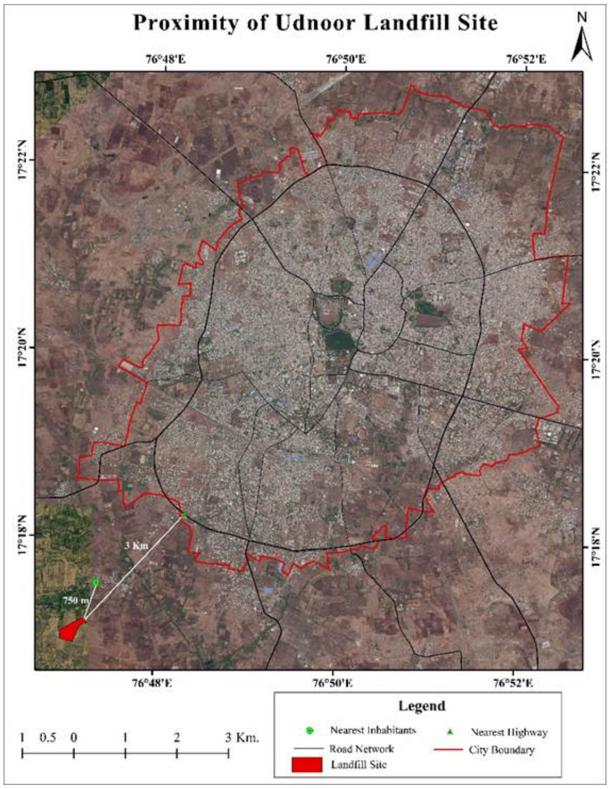

Fig. 6: Distance of Landfill Site from nearest inhabited place and National Highway

Recently, a unit for segregating and processing the collected waste was established within the landfill site. The process of refining reduces the total amount of waste deposited on the land by creating a significant amount of collected waste as compost. However, until 2022, collected waste was dumped on the land without segregation or processing, resulting in a larger volume of deposition and a higher risk of land degradation. Since the available space for waste disposal in the landfill site is minimal, a suitable site should be identified shortly for future use.

Adjacent to the area where this landfill is located are two waterbodies present. Even though this water body is not used by nearby residents, water from the water body serves as a drinking water source for cattle. The analysis of the satellite image of Google Earth shown in [Fig. 7] showed that one of the water bodies was there prior to the landfill being built [Fig. 8] and that the other water body began forming in or around 2022. This location is close to water sources, open areas of land used for agriculture and open scrublands that have raised serious concerns regarding the potential for groundwater contamination due to the open dumping of waste. The satellite image also showed evidence of leachate leaking out onto nearby open scrublands (marked by a red rectangle). Therefore, this location does not meet the guidelines for locating landfills, as stated in the Municipal Solid Waste Management Rules, 2016 [34]; thus, it may mitigate the potential adverse effects on the community and the local ecosystem.

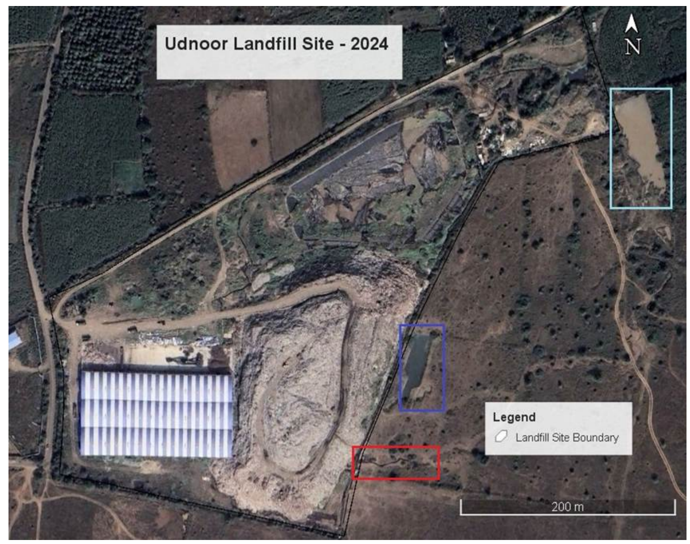

Fig. 7: Satellite Image of Existing Landfill Site at Udnoor

Fig. 8: Waterbody near Landfill Site

5 Discussion

The spatial assessment of SWM practices in Kalaburagi City, conducted using GIS tools, identify key spatial and operational shortcomings that reflect the same types of issues as in medium-sized Indian cities described previously, it is important to recognise that the effectiveness of SWM operations is very much contingent upon the availability of strategically placed waste collection infrastructures, such as waste bins. In addition, the high number of unauthorised dumpsite areas, coupled with poorly optimised routes for collecting waste, both contribute to the weakness of the linkages between waste generation patterns and collection infrastructure. Prior research studies have demonstrated the necessity of using geospatial data in making informed decisions regarding urban SWM [35, 36].

The spatial distribution of community waste bins in commercial areas along roads and their absence in residential areas represent another common problem in urban governance found in many Indian cities. In these cities, collection infrastructure often focuses on providing visible service to communities rather than equitably distributing service across all neighbourhoods [37]. This disparity between collection infrastructure and residential waste generation creates a void in service delivery and generates unregulated dumping locations, especially in high-density residential neighbourhoods. In Kalaburagi City, a total of 1432 unauthorised dumpsite locations were identified in or near roads and vacant plots. These illegal dumping locations contain large volumes of mixed waste materials, including organic waste, plastic, and paper. There are instances in certain areas where waste is being burned in open fires, generating additional air pollution in addition to creating unsightly conditions.

Additionally, because these locations are left uncleared for extended periods of time, they produce unpleasant odours, attract stray animals, serve as mosquito breeding grounds, and create visual pollution. Therefore, the results from this study demonstrate the failure of the D2D collection method to eliminate unregulated waste disposal methods in India. Other medium sized Indian cities, such as Mysuru and Nagpur, have similar spatial patterns associated with D2D collection service gaps and a lack of public awareness about service availability, resulting in the establishment of unregulated dumpsites even though regular collection services are available [38].

An examination of waste collection vehicle movements showed that the vehicles were utilising the same routes and exhibited inefficient transportation patterns, indicating significant operational inefficiencies in the current waste collection service. The inefficient transportation patterns not only increase fuel costs but also cause delays in collecting waste, increasing environmental and public health risks [39]. Kalaburagi's lack of properly planned routes to collect waste can be mitigated by using GIS-based optimisation studies that have been used to improve transportation efficiency in Indian cities such as Surat and Pune [40]. Specifically, the GIS-based algorithmic routing optimisations have improved transportation times and reduced operational costs for waste collection vehicles in those cities.

The spatial evaluation of the landfills in Kalaburagi demonstrates that the location of the landfill is proximal to water bodies, which would pose a serious issue according to national environmental regulations [34]. Additionally, the lack of provisions for future landfill site expansions at the existing landfill site highlights the need to identify a suitable new landfill site for future use.

6 Conclusion

This research used GIS-based spatial analysis to assess the present status of SWM in Kalaburagi city and analysed unauthorised dumpsites, community bins, transportation routes for waste and landfills in the city. The study found that there was an excessive amount of illegal dumping; waste collection bins were not uniformly distributed across the city; the routes of waste collection were poorly planned; and problems with the current landfill were identified and discussed. These problems in waste management point out some institutional and behavioural weaknesses in the city's strategy. It was noted that removing large community waste bins from the city and conducting D2D collections resulted in an increase in the number of open dumpings in the city, instead of decreasing them. Therefore, it is necessary to develop a suitable strategy to eliminate or significantly decrease the number of open dumps in the city, such as regular clean-ups, placement of waste bins in convenient locations, and educating residents about the importance of proper disposal of waste through public awareness campaigns and other related activities.

The optimal route assessment model in a GIS environment, incorporating the city's transportation network and waste generation sources, can reduce unnecessary repeated visits by more vehicles to a particular location and also reduce fuel and time consumption in the waste transportation process. The evaluation of the landfill site revealed that it is situated near waterbodies, with leachate leaking into them and the surrounding land. As the larger area of land site is already filled with solid waste, a new landfill location needs to be identified in the near future. The incorporation of site suitability analysis in GIS would help identify a suitable site in accordance with CPCB rules and regulations.

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