



GIS-Based Spatial Analysis of Solid Waste Generation and Disposal Sites in Indian Cities: Towards Sustainable Urban Waste Management

Ekta Yadav¹



<https://doi.org/10.55041/ijst.v2i6.179>

Cite this Article: Yadav, E. (2026). GIS-Based Spatial Analysis of Solid Waste Generation and Disposal Sites in Indian Cities: Towards Sustainable Urban Waste Management. *International Journal of Science, Strategic Management and Technology*, 02(6).
<https://doi.org/10.55041/ijst.v2i6.179>

License: This article is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting use, distribution, and reproduction in any medium, provided the original author(s) and source are properly credited.

The process of urbanisation in India has been a catalyst for economic development and a major challenge for the environment. Of these, management of municipal solid waste (MSW) has become one of the biggest challenges for the policy makers, urban planners and public health officials. India's urban population is expected to swell to almost 600 million by 2031, leading to an exponential increase in the amount of solid waste produced on a daily basis, which is already a significant burden on the already struggling municipal solid waste management systems in the country. Solid waste management is a complex problem that involves not only logistics but also a variety of disciplines, such as public health, environmental protection, city management and social equity. The mishandling of waste, such as negligent dumping, non-scientific landfill disposal and uncontrolled burning, has created significant consequences like ground water pollution, air pollution, vector-borne diseases and urban ecosystem degradation.²

There are many issues with the traditional waste management system in India. Manual collection, silo mentality and reactive disposal are common issues for municipal authorities. This leads to the rejection of waste in places which are not environmentally appropriate and socially just and which disproportionately impact on marginalised communities living near to waste disposal sites. Furthermore, lack of spatial information on waste generation makes it difficult for City Councils to implement effective waste collection schedules, deploy resources correctly and plan for future urban growth. On this occasion, Geographic Information Systems (GIS) are becoming a very powerful decision-support tool that can revolutionize waste management practices. GIS can be used to combine spatial and non-spatial data to visualize, analyse and model patterns of hotspot waste generation, collection logistics and the suitability of the disposal sites.³

Internationally, GIS has been used to successfully implement an optimized waste management system. Spatial analysis has been proven to reduce transportation costs, limit the environmental risks, and enhance the functioning of service delivery in European and North American studies. However, in

¹ Student, IGNOU, MSc Geoinformatics.

² Pankaj Bhattacharjee et al., GIS and Artificial Intelligence Based Solid Waste Management: A Comprehensive Case Study, *IJRAR* (2022).

³ Priyanka Shrivastava & Shivangi Mishra, A Review of Solid Waste Management Techniques Using GIS and Other Technologies, *ResearchGate* (2021).



developing countries the use of GIS has been limited, mainly because of resource limitations and a lack of technical knowledge.⁴ However, the promise is great. GIS can address this complexity and turn it into actionable insights for Indian cities, where waste amounts are highly diverse and change throughout the city based on the ward, socio-economic group and industrial cluster. GIS can be used to identify waste generation at the micro-level, then combine that data with other demographic, infrastructural and environmental information to determine where waste is being produced – as well as where it needs to be disposed of to cause the least harm and to be as efficient as possible.⁵

The magnitude of the waste problem in India highlights the need for GIS based approaches. Indian cities produce more than 150,000 metric tonnes of solid waste every day, with metros such as Delhi, Mumbai and Bengaluru accounting for disproportionate share of the waste.⁶ Many of these wastes are dumped in landfills, many of which are poorly managed and are a serious environmental threat. Ghazipur landfill in Delhi, for example, has emerged as a symbol of the problem, rising above the city and releasing toxins into nearby water supplies. These are just a few examples that show the critical need for scientific site selection and monitoring systems. GIS-based suitability analysis, which takes into account factors like distance from residential areas, groundwater vulnerability, land use, and accessibility, can be used to systematically identify optimal disposal sites. This not only lowers environmental hazard potential, but also makes waste facilities more socially acceptable because they are sited in areas where community exposure is minimized.⁷

GIS is not only about selecting waste disposal sites, it can revolutionize the collection and transportation of waste. The inefficiency of the routing is a major source of high cost and low effectiveness of municipal waste systems. Trucks usually do not use optimized routes for collection, resulting in fuel wastage and late collections. Using GIS-based network analysis, the City can plan routes that minimize travel time and distance traveled and maximize service coverage. This impacts directly on greenhouse gas reduction, reduced operational costs and better service delivery. Additionally, if GIS is coupled with GPS and RFID technologies, it can support real-time measurement of waste flows, forming a responsive system that employs GIS to adjust to changing urban conditions.⁸

GIS also supports the policy initiatives of India in waste management. The concept of 'Cleanliness and Sanitation' under the Swachh Bharat Mission focuses on cleanliness and sanitation, whereas the concept of 'Smart Cities' under Smart Cities Mission is centered on the use of technology in urban governance. GIS-based waste management systems represent the latest in technological advancements and practical solutions for cities, reflecting the core tenets of these missions. Furthermore, the Solid Waste Management Rules, 2016, lay down scientific processing and disposal of waste giving a regulatory mechanism, which can be enhanced by the GIS applications.⁹ Through this integration of GIS into city planning, cities can strive to meet national laws and international sustainable development commitments, such as the United Nations Sustainable Development Goals (SDGs), specifically SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production).

Although a great deal is possible with GIS, there are challenges associated with its use in Indian waste management. Availability and quality of data continues to be a major challenge. The municipal records are frequently incomplete and inconsistent in some cases, which can make it challenging to develop

⁴ Springer, GIS-Based Infrastructure Development for Municipal Solid Waste Management (2020).

⁵ NIUA, Application of Geospatial Tools in Municipal Waste Management (2022).

⁶ MapmyIndia, Solid Waste Management Solution to Make India Clean (2017).

⁷ GIS Driven Solutions, GIS Driven Solution for Improving Solid Waste Management in India (2026).

⁸ Id.

⁹ Ministry of Environment, Forest & Climate Change, Solid Waste Management Rules, 2016 (India).



reliable spatial databases. Another restriction is the lack of technical expertise; there are many municipal corporations that do not have trained staff for the operation of GIS systems. The cost is another reason that the widespread use of this technology is restricted, especially in smaller cities that lack the budgets for such investments. Capacity building, investments in technology, and cooperation between government institutions, academic institutions and private partners will be required to overcome these challenges. The implementation of GIS-based waste management has been showcased in various cities, including Pune and Bengaluru, and has proven its viability; however, scaling these initiatives to different urban settings will require commitment and innovation.¹⁰

This is one of the research papers which aims at contributing to this growing discipline in the light of the possibility of mapping solid waste generation and disposal sites using the GIS in Indian cities. The study will establish a spatial model to reflect the spatial variation in waste generation, assess the capacity of the current disposal facilities and recommend scientifically sound alternatives. The research will show how GIS can be used in practice, showing various opportunities and limitations by selected case studies. The ultimate objective is to offer policy and decision makers with hands-on information to inform efficient, sustainable and socially just waste management systems for municipal authorities that enable them to reach their policy objectives.

This research is focused on technology, policy and urban governance. It acknowledges that waste management is a socio-political challenge and calls for participatory planning and community involvement. GIS can be a tool for participatory governance, giving citizens access to and transparency of spatial data, and enabling them to hold authorities accountable and participate in decision-making. It is consistent with the overall concept of sustainable urban development, in which technology is used not just for efficiency, but also for equity and justice.

Finally, the adoption of GIS in SWM is a paradigm shift in Indian cities. It provides a way to break the cycle of reactive, ad hoc practices and get into the habit of more proactive, data-driven planning. GIS can be used to create cleaner, healthier and more sustainable cities by mapping out the location of waste generation and disposal sites, analysing spatial distribution and incorporating environmental and social factors. Hence, the research is timely and necessary as it is a gap in urban planning and an integral part in the vision of smart and sustainable cities in India.

REVIEW OF LITERATURE

The management of solid wastes is one of the key issues in urban governance, especially in countries undergoing rapid urbanisation like India. The literature confirms that the problem is multidimensional, namely environmental, social, economic and legal aspects. As a result, scholars have repeatedly stated that traditional waste management systems, which are based on manual collection and scientific disposal, are inefficient to deal with the scale and complexity of urban waste. The use of Geographic Information Systems (GIS) in waste management has therefore been seen as a promising innovation, as they provide spatially informed solutions that can help improve efficiency, sustainability, and equity.¹¹

Worldwide, GIS has been used extensively in waste management with good results. In Europe, models have been developed to optimize collection operations, using GIS to minimize environmental effects and the costs of the operations.¹² Likewise, some research in North America has shown how spatial analysis

¹⁰ Press Information Bureau, Solid Waste Management Rules, 2016: What is New? (2016).

¹¹ Pankaj Bhattacharjee et al., GIS and Artificial Intelligence Based Solid Waste Management: A Comprehensive Case Study, IJRAR (2022).

¹² Springer, GIS-Based Infrastructure Development for Municipal Solid Waste Management (2020).



can be used to select a landfill site that takes environmental sensitivity, accessibility and community acceptability into consideration in the decision making process. The experiences described internationally highlight the versatility of GIS in combining a variety of data sets and generating actionable information. They also identify the need to adapt GIS methodology to local contexts, as there are differences in waste composition, urban morphology and governance structures.

The literature in the Indian context highlights potential challenges and opportunities related to the use of GIS in waste management. Shrivastava and Mishra conduct a detailed analysis of the applications of GIS in Indian cities and highlight that while these were successfully piloted, there was a lack of widespread use owing to resource constraints and lack of technical skills among the users.¹³ They note that GIS can be especially useful for identifying hot spots of waste generation, which can be very different within socio-economic groups and industrial clusters. This heterogeneity captures the potential for more targeted interventions that can therefore be more efficient and effective, and reduce inequities.

Specific case studies of cities in India further highlight the potential of GIS. For example, GIS mapping has helped to find the best routes for collection in Pune and has saved a lot in terms of fuel usage and operational costs.¹⁴ By combining environmental and demographic data, Bengaluru has used GIS to track waste flows and evaluate landfill suitability, reducing risks. The examples show that GIS can be used in a variety of urban settings, as long as efforts are made to build GIS capacity and data infrastructure within municipalities. They also stress the need for community involvement in the process, since solutions that rely on GIS must take into account community concerns and the importance of local knowledge.

The legal & policy landscape in India is conducive for the adoption of GIS in waste management. As per Solid Waste Management Rules, 2016, scientific processing and disposal of waste has been made mandatory with the thrust on environment friendly practices.¹⁵ These regulations are consistent with the international standards like that of European Union Directives on Waste Management that encourage sustainable disposal and recycling.¹⁶ Integrating GIS into urban planning can help Indian cities achieve these standards and improve environmental sustainability and public health. Furthermore, national programs like 'Swachh Bharat Mission' and 'Smart Cities Mission' explicitly endorse the use of technology in urban governance, which opens up possibilities for GIS-based innovations.¹⁷

However, there are also great challenges in the literature. Availability and quality of data are still a significant challenge as municipal data is restricted, inconsistent or stale. GIS models need accurate data to provide accurate and actionable insights. Another limitation is technical expertise, with many municipal corporations not having trained staff to run GIS systems. Financial constraints also play a role, especially for smaller cities that lack budgets. Solving these challenges will need a multi-faceted strategy that encompasses technology investment, capacity development, and partnerships among government, academia and private sector.

There are also references in the literature of the value of combining GIS technologies with other technologies. For instance, Bhattacharjee et al. note that GIS could be used in conjunction with artificial

¹³ Priyanka Shrivastava & Shivangi Mishra, A Review of Solid Waste Management Techniques Using GIS and Other Technologies, ResearchGate (2021).

¹⁴ NIUA, Application of Geospatial Tools in Municipal Waste Management (2022).

¹⁵ Ministry of Environment, Forest & Climate Change, Solid Waste Management Rules, 2016 (India).

¹⁶ European Union, Directive 2008/98/EC on Waste (2008).

¹⁷ Press Information Bureau, Solid Waste Management Rules, 2016: What is New? (2016).



intelligence (AI) to develop predictive models of waste generation and disposal. These models can predict future trends, allowing municipalities to plan ahead instead of after the fact. Likewise, the combination of GIS, GPS and RFID can help to monitor waste flows in real time, which can create dynamic systems that adapt to the variability of urban conditions. These innovations are the evolution needed to shift from mapping to governance of waste, and will unlock the potential for more interactive, data-driven governance.¹⁸

Literature puts waste management from a GIS perspective in the context of wider concepts of urban ecology and environmental justice from a theoretical perspective. Urban ecology focuses on the interdependence of humans and nature, and requires an integrated approach to waste management.¹⁹ Environmental Justice, on the other hand, highlights the unequal allocation of waste-related risks, especially for the marginalized communities residing close to waste disposal sites. GIS can be used as a tool for participatory governance which makes spatial data available and transparent, and allow citizens to hold authorities accountable and participate in decision making. This reflects the overall concept of sustainable urban development that technology is not only used to be effective but also to be fair and just.²⁰

Finally, literature shows ample support to integrate GIS in Indian city of SWM. It emphasizes the possible benefits of spatial analysis such as efficiency, minimizing environmental risks and social equity. Meanwhile, it acknowledges the issues of data quality, technical know-how and financial limitations. Indian cities can learn from experiences around the world and tailor GIS approaches to local contexts to create scientifically sound, socially responsive waste management systems. However, this study aims to extend this work and add to the growing body of GIS-based waste management, by examining the use of GIS in a few selected cities of India and outlining a spatial strategy for sustainable urban governance.

DATA ANALYSIS

The results obtained from the mapping exercise of solid waste generation and disposal locations in Indian cities using GIS in the context of urban sustainability and governance should be interpreted. The existence of the waste generating hotspots, as revealed by their spatial distribution, not only indicate heterogeneity of urban consumption, but also highlight inequities in municipal service delivery. For example, informal settlements are frequently areas of waste generation, but they are sparsely provided for in terms of waste collection services, which results in open dumping and public health hazards. It highlights the importance of GIS as a social justice instrument that can be used to ensure equitable distribution of resources among various urban communities.²¹

The analysis of disposal sites also emphasizes the environmental characteristics of the existing disposal practices. There are many landfills in place that are not scientifically sited as required under Solid Waste Management Rules, 2016, in environmentally sensitive areas, near water bodies and residential areas.²² GIS-based suitability models are able to combine environmental, demographic, and infrastructure data to systematically assess alternative sites for their ecological risk and community acceptance.²³ This is in

¹⁸ Bhattacharjee et al., *supra* note

¹⁹ Brian Walker et al., *Urban Ecology and Resilience in Cities*, Ecology & Society (2010).

²⁰ Robert Bullard, *Dumping in Dixie: Race, Class, and Environmental Quality* (1990).

²¹ Robert Bullard, *Dumping in Dixie: Race, Class, and Environmental Quality* (1990).

²² Ministry of Environment, Forest & Climate Change, *Solid Waste Management Rules, 2016* (India).

²³ NIUA, *Application of Geospatial Tools in Municipal Waste Management* (2022).

line with the international best practices like the European Union’s directive on waste management that focuses on environmentally sound disposal and recycling.²⁴

The other key issue is collection and transportation efficiency. The result of GIS based route optimization has huge potential to cut down operational cost and greenhouse gas emission. Spatial analysis can help to optimise collection logistics and deliver measurable benefits to service delivery as demonstrated in case studies from Pune and Bengaluru. It is noted, however, that literature warns that such efficiencies depend on having accurate data and ability of institutions to put GIS suggestions into practice.²⁵ The GIS models can become a static map if there is no strong data infrastructure and trained people.

GIS is also contextualized in the Indian policy domain. Technology has been explicitly promoted in urban governance through various initiatives at the national level like Swachh Bharat Mission and Smart Cities Mission.²⁶ GIS-based waste management systems represent these missions, and can be considered as a technological innovation, as well as a practical solution in urban management. Furthermore, the use of GIS in city planning can help to ensure compliance with the Solid Waste Management Rules, 2016, thus enhancing the regulatory enforcement and accountability. This is an intersection of technology and policy and highlights the relevance and current adoption of GIS in the cities of India.

Comparative Table: GIS-Based Solid Waste Management in Indian Cities

City/State	Waste Generation (Approx.)	GIS/Geospatial Application	Key Innovations	Challenges	Outcomes
Delhi (North Delhi)	~11,000 MT/day	GIS used for landfill management and monitoring	Mapping of landfill zones, integration with C&D waste tracking	Overcapacity landfills (e.g. Ghazipur), poor segregation	Partial success highlighted need for scientific site selection
Pune (Maharashtra)	~1,300–1,400 MT/day	GIS applied for route optimization, site suitability analysis	Ward-wise mapping, GPS enabled trucks, landfill suitability studies	Rapid urban growth, inconsistent segregation	Improved collection efficiency, reduced fuel costs
Bengaluru (Karnataka)	~4,500 MT/day	GIS for monitoring waste flows and technological innovation	Integration with IoT sensors, landfill suitability mapping	High population density, informal settlements	Enhanced monitoring, but scaling remains a challenge
Jaipur (Rajasthan)	~1,200 MT/day	GIS used in pilot projects under	Training modules for municipal staff	Limited technical expertise,	Early-stage adoption;

²⁴ European Union, Directive 2008/98/EC on Waste (2008).

²⁵ Priyanka Shrivastava & Shivangi Mishra, A Review of Solid Waste Management Techniques Using GIS and Other Technologies, ResearchGate (2021).

²⁶ Press Information Bureau, Solid Waste Management Rules, 2016: What is New? (2016).

		NIUA's Sustainable Cities initiative	suitability analysis	budget constraints	promising for replication
Aurangabad (Maharashtra)	~300 MT/day	GIS for bin allocation and collection route planning	Suitability analysis for waste bin placement, recyclable bin proposals	Lack of segregation awareness	Improved convenience, reduced collection workload
Indore (Madhya Pradesh)	~1,100 MT/day	GIS integrated with source segregation and processing	Ward-level segregation mapping, composting facilities	Scaling segregation across all wards	Ranked India's cleanest city, strong citizen participation
Mysuru (Karnataka)	~400 MT/day	GIS applied in biodegradable waste management	Decentralized composting, GIS-based monitoring	Limited landfill space	High success in community-driven waste segregation

Summary of Key Findings

- **Waste Generation Hotspots:** GIS mapping reveals that urban wards with high population density and informal settlements are major contributors to municipal solid waste, yet they often remain underserved by collection services.
- **Disposal Site Inefficiencies:** Existing landfills in cities like Delhi and Bengaluru are located in environmentally sensitive zones, violating scientific site selection principles and contributing to groundwater contamination and air pollution.
- **Route Optimization Potential:** Case studies from Pune and Indore show that GIS-based route planning reduces fuel consumption, operational costs, and greenhouse gas emissions, while improving collection efficiency.
- **Policy Alignment:** GIS applications align with national initiatives such as the Swachh Bharat Mission and Smart Cities Mission, and support compliance with the Solid Waste Management Rules, 2016.
- **Challenges Identified:** Data quality, lack of technical expertise, and financial constraints remain major barriers to scaling GIS-based waste management across Indian cities.
- **Community Engagement:** GIS platforms can democratize data, enabling citizens to monitor waste flows and hold municipal authorities accountable, thereby advancing environmental justice.

CONCLUSION

The use of Geographic Information Systems in the management of solid waste is a transformative opportunity for Indian cities. This chapter highlights the benefits of GIS in resolving some of the major challenges involved in generating, locating, and planning waste sites and routes. GIS offers municipalities a tool for spatially informed planning, helping to shift the conversation from the purely reactive to the



more proactive, data-driven approach. In an era of rapid urbanization and an ever-growing consumption base, the change is necessary because it adapts to the needs of waste management.

Comparative study of cities like Delhi, Pune, Bengaluru, Indore shows the possibilities as well as the challenges in the application of GIS. Cities such as Pune and Indore have successfully used GIS services for route optimization and town faulting and have engaged citizens but the metros such as Delhi are yet to face problems with the overcapacity landfill and lack of segregation. These contrasts emphasize the need for local context specific adaptations of GIS applications, such that technological solutions are relevant to and responsive to the socio-economic and infrastructural contexts of each city.

Policy-wise, GIS will support implementation of the Solid Waste Management Rules, 2016 and tie up with India's urban initiatives such as the Smart Cities Mission and the Swachh Bharat Mission. Furthermore GIS based waste management plays a direct role in pursuing international sustainability objectives, especially the United Nations Sustainable Development Goals for sustainable cities and responsible consumption. Indian cities can support environmental sustainability, public health and social equity in their planning activities with the integration of GIS.

However, issues around data quality, technical ability, and funding demand to be tackled to unlock the value of GIS. Investment in spatial databases, capacity development for city officials and joint efforts between public, academic and private sector are necessary. Community involvement is also crucial, as GIS could give citizens a platform to play a role in waste governance and facilitate democratic urban planning and promote environmental justice.

Thus, it could be concluded that GIS mapping solid waste generation and disposal sites provide a replicable and scalable model for sustainable urban governance in India. It connects technology, policy, and community, creating a comprehensive approach to cleaner, healthier, and fairer cities. This chapter highlights the need to use GIS in Waste Management and paves the way for future research to incorporate GIS with other emerging technologies like artificial intelligence and IoT to transform the vision of Smart and Sustainable India.