

Circular Economy Models in Urban Solid Waste Management

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Abstract - This study explores how Circular Economy (CE) principles can transform urban solid waste management (SWM) in Indian cities, focusing on Lucknow's Alambagh and Ashiyana-Vrindavan Yojna zones. It addresses the shift from conventional linear systems—based on collection and disposal to more sustainable, closed-loop models that emphasize waste minimization, resource recovery, and inclusive governance. Using a mixed-methods approach, including household surveys, stakeholder interviews, and policy analysis, the research identifies key challenges and opportunities in Lucknow's waste ecosystem. It proposes a city-specific CE framework incorporating decentralized composting, bio-CNG production, IoT-enabled smart bins, and incentive-driven citizen participation. The model is benchmarked against national and global case studies such as Indore, Pune, and Norway to ensure adaptability and effectiveness. The framework aligns with national missions like Swachh Bharat Mission 2.0 and UN Sustainable Development Goals (SDG 11 and 12), offering a scalable strategy for cleaner, greener, and more resilient urban futures.

Key Words: Circular Economy, Urban Solid Waste Management, Kano Model, Smart Governance, SDG 11 & 12

1. INTRODUCTION

India's rapid and unplanned urbanization has significantly strained existing municipal services, particularly solid waste management (SWM), which has long relied on a linear "collect, transport, and dump" model. This outdated system has led to overburdened landfills, unsegregated waste streams, environmental degradation, and public health risks. Recognizing these challenges, the present study explores the application of Circular Economy (CE) principles to redesign urban SWM systems as closed-loop, resource-efficient processes that emphasize waste prevention, reuse, recycling, and recovery.

Lucknow, one of India's fastest-growing cities, was selected as the primary study area due to its large and diverse population, policy momentum under Smart City and Swachh Bharat Mission initiatives, and growing urban sprawl. Within Lucknow, the zones of Alambagh and Ashiyana-Vrindavan Yojna were chosen as representative case areas. Alambagh is a high-density, older mixed-use area with significant informal activity and high daily waste volumes, while Ashiyana-Vrindavan Yojna is a relatively

planned colony with middle-income residential zones, emerging markets, and evolving civic infrastructure.

The contrast between these two zones allowed the research to assess circular interventions across different urban typologies. The aim was to identify scalable and inclusive CE models tailored to each context while offering insights applicable to other Indian urban areas facing similar solid waste challenges.

2. AIM

To develop a circular economy-based framework for urban solid waste management in Lucknow by assessing current waste management practices, identifying challenges, and proposing policy, technological, and infrastructural solutions.

3. OBJECTIVE

Objective 1: To Identify barriers to circular economy implementation, including policy gaps, financial constraints, and technological limitations.

Objective 2: To Analyze successful circular economy waste management models (e.g., Indore, Pune, Mysuru, global case studies) for benchmarking best practices.

Objective 3: To Propose a circular economy waste management framework for Alambagh & Kanpur Road Scheme, Lucknow, integrating:

- Decentralized composting & biogas plants for organic waste.
- AI-driven waste sorting & IoT-based tracking systems.
- Public-private partnerships (PPPs) for sustainable waste processing units.
- Financial incentives & Extended Producer Responsibility (EPR) models.

4. RESEARCH QUESTION

Primary Research Question:

How can Lucknow transition to a circular economy-based urban solid waste management system to achieve sustainability and waste reduction?

Secondary Research Questions:

- What policy interventions and financial incentives are necessary for Lucknow to adopt a circular waste management system?
- How can smart technologies (AI, IoT, blockchain) improve waste collection, sorting, and recycling efficiency?

5. METHODOLOGY

The research adopted a **mixed-methods design** to comprehensively examine the integration of circular economy (CE) principles into urban solid waste management (SWM) in Lucknow. The methodology involved both qualitative and quantitative techniques, ensuring a holistic understanding of existing systems, stakeholder perceptions, and potential interventions.

Step 1: Primary Data Collection

Field surveys were conducted across approximately 250 households in Alambagh and Ashiyana-Vrindavan Yojna to capture resident behavior, awareness, and attitudes towards waste segregation, recycling, and composting. Structured interviews were held with key stakeholders, including officials from the Lucknow Municipal Corporation (LMC), informal waste workers, recyclers, and local startups engaged in waste processing. Additionally, on-site **waste audits** were carried out to quantify and categorize household and market waste types.

Step 2: Secondary Data Review

Relevant policies, municipal records, Swachh Bharat Mission progress reports, and global CE case studies were analyzed to benchmark best practices and understand regulatory frameworks.

Step 3: Kano Model Application

A set of 26 SWM service features ranging from door-to-door collection, smart bins, to compost return incentives were selected. These features were evaluated through Kano questionnaires administered to residents. Responses were classified into five categories: Must-be, Performance, Attractive, Indifferent, and Reverse, offering empirical insights for designing citizen-centric CE strategies and policy recommendations.

6. LITERATURE STUDY

A comprehensive review of key reports and studies was undertaken to frame the theoretical and policy basis for circular economy (CE) integration in urban solid waste management (SWM).

A. MoHUA Report: Framework for Transitioning Indian Cities to CE Waste Models (2021)

Published by the Ministry of Housing and Urban Affairs, this report emphasizes enabling policies, institutional reforms, economic incentives, and decentralized infrastructure. It advocates integration of CE in City Sanitation Plans, Extended Producer Responsibility (EPR), and Material Recovery Facilities (MRFs) at ward levels. Innovations include digital waste tracking, PPP-based infrastructure, and inclusive planning. However, gaps include insufficient financial models and weak applicability to smaller cities.

B. Comparative Study: Toward Zero-Waste Cities (2024)

This paper analyzes Indore, Pune, and global cities (San Francisco, Ljubljana, Tokyo), highlighting their success in decentralized systems, informal sector integration, and citizen engagement. Indore's bio-CNG plant and Pune's SWaCH cooperative serve as scalable models. Global practices stress public education, detailed segregation systems, and extended producer responsibility.

C. Driving Sustainability: Circular Economy in Waste Management (2021)

This study outlines CE's foundational objectives: eliminate waste, circulate resources, and regenerate nature. It presents international models (e.g., Amsterdam, Tokyo), policy alignment with SBM-U 2.0 and GOBARdhan, and highlights the importance of local infrastructure, source segregation, and behavior change campaigns.

D. Transitioning Indian Cities into Circular Economy (2022)

Focuses on governance challenges and recommends reforms such as CE roadmaps, capacity building, CE Cells in ULBs, PPP models, and digital dashboards. Highlights issues like weak enforcement, data absence, funding gaps, and informal sector neglect.

Conclusion:

The literature establishes CE as a multi-dimensional strategy requiring integrated governance, digital tools, decentralized solutions, and community participation. However, implementation success depends on context-specific frameworks, financial support, and strong institutional coordination.

7. CASE STUDY

A. Case Study 1: Indore, Madhya Pradesh – India's Circular Waste Management Pioneer

Indore, with a population of ~3.5 million, has been ranked India's cleanest city (2017–2022) and serves as a national benchmark for circular solid waste management (SWM). Before 2016, the city struggled with open dumping, unsegregated waste, and poor public engagement. Indore's transformation was driven by the Indore Municipal Corporation (IMC) through a multi-pronged strategy:

- **100% Source Segregation** with 6 waste categories
- **Decentralized composting and Material Recovery Facilities (MRFs)** in all 85 wards
- **Asia's largest Bio-CNG plant**, processing 550 TPD of wet waste
- **Public-private partnerships** and GPS-fitted vehicles for real-time waste monitoring
- **Intensive IEC campaigns**, Swachhata Doots, and formalization of waste pickers into SHGs

Source : WASTE-WISE CITIES Best practices in municipal solid waste management – by NITI Ayog

Steps taken by IMC to reform its waste management system

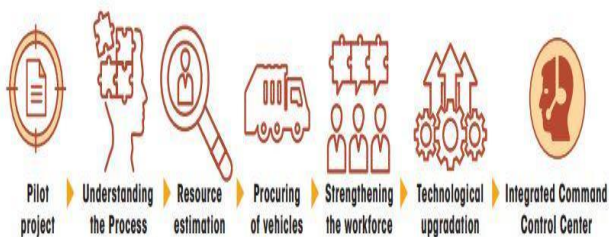


Figure 4 - The process outlined was followed by Indore Municipal Corporation

The city achieved **zero landfill status** and recovered over 90% of its waste, generating daily revenues via compost sales, user charges, RDF, and carbon credits. Lessons highlight the importance of decentralization, digital governance, community mobilization, and strong political-administrative will.

B. Case Study 2: Norway – A Technologically Advanced Circular Waste Model

Norway presents a highly institutionalized CE model with advanced technology, strong legal frameworks, and high citizen compliance. With a <1% landfill rate and >95% household-level segregation, the country exemplifies closed-loop waste systems.

- **Strict EPR compliance** for packaging, electronics, and vehicles
- **Deposit Refund Systems (DRS)** yielding 95%+ return rates

- **Automated MRFs**, district heating from energy recovery, and AI-based waste sorting
- **Digital tools and apps** for waste tracking and citizen rewards.

Norway recycles ~45–50% of waste and recovers energy from ~52%, using waste-to-energy for district heating. Governance is overseen by the **Norwegian Environment Agency** and aligned with EU CE Action Plans. While it leads in efficiency and awareness, the model faces concerns around high incineration dependency and gaps in reuse/repair systems.

Conclusion:

Both Indore and Norway demonstrate that CE in SWM is achievable through strong governance, community inclusion, and scalable innovations. Indore offers a replicable model for Indian cities with moderate resources, while Norway illustrates the role of policy coherence, technology, and EPR in achieving advanced CE outcomes.

8. STUDY AREA

The study focuses on **Zones 5 (Alambagh)** and **Zone 8 (Ashiyana-Vrindavan Yojna)** of **Lucknow**, a rapidly urbanizing Tier-2 city in North India. These two zones present contrasting yet complementary urban typologies, making them ideal for testing scalable circular economy (CE) interventions in solid waste management.

Zone 5: Alambagh Region

Alambagh is characterized by dense, organically developed residential and commercial settlements. It includes localities such as RDSO Colony, Krishna Nagar, Geeta Palli, and Baldi Khera. The population is estimated at 1.2–1.5 lakh, comprising middle-income households, traders, and migrant workers. Due to its proximity to major transport hubs and markets, it generates high volumes of unsegregated waste and faces infrastructural stress.

Zone 8: Ashiyana-Vrindavan Yojna Cluster

Zone 8 covers around 1.5–1.8 lakh residents and includes over seven dozen planned neighborhoods such as Eldeco Udyan, Vrindavan Yojna, and LDA colonies. These areas have better civic infrastructure, active RWAs, and a higher literacy rate, which enables more consistent waste segregation and community-led initiatives.

Solid Waste Infrastructure Highlights

- Over **60 GPS-equipped tippers** operate in Zones 5 and 8.

- **Fixed Compactor Transfer Stations (FCTS)** at Bhaishora and Kesari Khera ensure safe waste transportation.
- **Shivri Processing Plant** handles up to 2,000 TPD, with RDF, composting, and biomining facilities.
- **CSR-funded ward-level composters** and a **5 TPD bio-CNG pilot** are operational in Vrindavan Yojna.
- **IoT-enabled smart bins** and real-time waste tracking apps aid operational efficiency.

Socio-Economic and Institutional Capital

- Presence of over **40 active RWAs**, eco-clubs, and trader associations.
- High levels of public awareness due to Swachh Bharat Mission campaigns.
- Informal waste workers have potential for cooperative integration and formalization.

Challenges & Opportunities

The key challenges include inconsistent source segregation in high-density pockets, resistance to formalization among informal workers, and financing smart waste systems. However, both zones exhibit readiness in terms of logistics, citizen engagement, and infrastructure to pilot decentralized, CE-based waste management strategies.

9. KANO ANALYSIS

To assess user satisfaction with proposed circular economy (CE)-based solid waste management (SWM) features, the study employed the **Kano Model**. A total of **26 features (F1–F26)** were evaluated through structured household surveys in Alambagh and Ashiyana-Vrindavan Yojna zones. Respondents were asked to categorize each feature based on its perceived impact on satisfaction.

A. Classification of Features

- [1] **Attractive (A):** 8 features – these features delight users unexpectedly and significantly boost satisfaction. Examples include real-time waste tracking apps, AI-based smart bins, gamified segregation tools, and compost giveaways.
- [2] **Performance (P):** 7 features – directly linked to user satisfaction. The better the performance, the higher the satisfaction. Key examples are door-to-door collection (F1), incentives for household segregation (F3), and waste-to-energy infrastructure (F22).
- [3] **Must-Be (M):** 3 features – basic expectations. Their absence leads to high dissatisfaction. F5 (community composting centers) scored the

highest (8.33) among these, signaling its critical importance.

- [4] **Indifferent (I):** 7 features – do not significantly impact user satisfaction. These can be deprioritized unless justified for backend efficiency.
- [5] **Reverse (R):** 1 feature – found to reduce satisfaction, suggesting potential misalignment with user needs or poor communication.

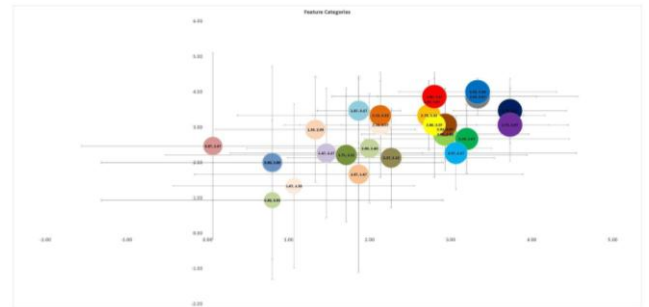


Figure - Kano Analysis Graph

Source - Interpreted by Author in 2025

B. Importance Scores

- **Performance features** had the highest average importance score (7.62), followed closely by Must-Be features (7.51).
- **Attractive features** scored moderately (6.1), indicating good potential for enhancing user experience post-basic infrastructure rollout.
- **Indifferent and Reverse features** averaged 5.46 and 5.6, respectively, requiring minimal initial investment.

C. Policy Implications

- **Must-Be features** must be prioritized as "hygiene factors" and foundational infrastructure.
- **Performance features** should be enhanced through measurable KPIs such as efficiency, frequency, and service quality.
- **Attractive features** serve as innovation levers and should be phased in via pilot projects and IEC campaigns.
- **Indifferent and Reverse features** should be re-evaluated periodically as user expectations evolve.

D. Strategic Outcomes

The Kano Analysis guided the development of a citizen-centric and inclusive CE framework, aligning with SDG 11 & 12, Swachh Bharat Mission-U 2.0, and Smart City KPIs. It

emphasized that blending core services with innovation and behavioral incentives is key to creating sustainable and responsive urban waste systems.

10. POLICY & PROPOSALS

The thesis proposes a comprehensive policy shift from linear to circular urban solid waste management (SWM), emphasizing stakeholder inclusion, decentralization, technological adoption, and fiscal innovation. Based on empirical findings and best practices, an **Integrated Incentive-Based Policy Framework** is recommended.

A. Policy Implications

[1] Policy-Implementation Gap:

Despite strong national frameworks, implementation at ward and city levels remains weak due to lack of accountability, capacity, and data-driven governance.

[2] Need for Informal Sector Inclusion:

Informal workers are crucial for material recovery but remain unrecognized. Policy must provide social security, formal contracts, and cooperative formation support.

[3] Digitalization and Transparency:

There is a growing need for digital tools (IoT bins, mobile apps, dashboards) to enable real-time waste tracking, citizen incentives, and transparent service monitoring.

[4] Financial Constraints:

ULBs lack adequate funding to scale CE systems. Municipalities must leverage green bonds, CSR, and PPPs for CE infrastructure.

B. Strategic Proposals

1. Citizen Incentives and Behavior Change

- **Property Tax Rebates** for compliant households
- **Digital Reward Apps** for recyclable and compostable contributions
- **Public Recognition** for zero-waste communities

2. Informal Sector Empowerment

- **Skill Training with Certification**
- **Social Security Enrollment** (health, pension, accident cover)
- **Minimum Support Prices** via buy-back centers for dry recyclables

3. Decentralized Infrastructure Support

- **Capital Subsidies (40–50%)** for composting/MRF/biogas units

- **Subsidized Land Leasing** for waste infrastructure
- **Three-Year O&M Grants** to ensure viability of decentralized models

4. Private Sector and PPP Involvement

- **Viability Gap Funding (VGF)** to reduce investment risk
- **Performance-linked Incentives** for CE service providers
- **Fast-track Clearances** for waste-tech startups

C. Implementation and Monitoring Framework

- **City-Level CE Cells** for coordination and adaptive planning
- **Ward-Level Committees** for participatory feedback and oversight
- **KPIs and Open Dashboards** for performance tracking
- **Independent Audits** to ensure fair and transparent incentive distribution.

Conclusion

This policy framework bridges institutional gaps and incentivizes key stakeholders citizens, ULBs, private sector, and the informal workforce to co-create a sustainable and circular urban waste ecosystem. When supported by technology and inclusive governance, the framework can be scaled across Tier-2 and Tier-3 Indian cities.

11. CONCLUSION

This research has explored the urgent need to transition urban solid waste management (SWM) systems in Indian cities from linear, inefficient models to circular economy (CE)-based frameworks. Through an in-depth case study of Lucknow specifically the zones of Alambagh and Ashiyana-Vrindavan Yojna the study demonstrates how decentralized infrastructure, smart governance tools, and community participation can collectively build a resilient and sustainable waste ecosystem.

Key findings highlight the public's preference for features such as door-to-door collection, decentralized composting, waste-to-energy solutions, and incentive-based participation. The application of the Kano Model provided empirical classification of 26 SWM features, ensuring user-centered design and service delivery planning.

The research culminates in the proposal of an integrated, incentive-based CE policy framework. This includes financial instruments, stakeholder mandates, institutional reforms, and digitalization strategies. Additionally,

recommendations focus on integrating the informal sector, enabling public-private partnerships, and aligning local initiatives with national programs like SBM-U 2.0, Smart Cities Mission, and SDGs 11 and 12.

In conclusion, the proposed CE framework is not only scalable across Indian Tier-2 cities but also adaptable to varied socio-economic contexts. With the right mix of policy will, financial support, and community engagement, the path toward a zero-waste, circular urban future is both achievable and imperative.

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