CIRCULAR ECONOMY MODELS IN URBAN SOLID WASTE MANAGEMENT

Thesis Submitted in Partial Fulfilment of the requirements

for the award of the degree of

MASTERS IN URBAN PLANNING

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Under The Guidance of

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UNDERTAKING

I, Mr. Neeraj Kushwaa, the author of the thesis titled “CIRCULAR ECONOMY MODELS IN URBAN SOLID WASTE MANAGEMENT”, hereby declare that this is an independent work of mine, carried out towards fulfilment of the requirements for the award of the Masters in Urban & Regional Planning at the Department of Architecture and Planning, BBDU, Lucknow. The work has not been submitted to any other organization / institution for the award of any Degree/Diploma. …….

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Date: 10,June,2025

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I express my profound gratitude to all those who have played an essential role in the successful completion of this thesis, titled **"Circular Economy Models in Urban Solid Waste Management."** This academic journey has been one of the most enriching and transformative phases of my professional life.

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I would also like to acknowledge the valuable support of urban planners, municipal officials, local experts, and Gomti Nagar residents who shared their insights and participated in surveys and interviews. Their inputs were instrumental in shaping the practical framework and grounding my research in local realities.

A heartfelt appreciation goes to my parents and family members, whose unconditional love, blessings, and support gave me strength during difficult times. Their belief in my capabilities kept me focused and determined to complete this thesis with sincerity and dedication.

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Lastly, I would like to thank my son, Mr. Vibhuti Narayan Kushwaha, for assisting with the typesetting of this thesis.

This thesis is not just a culmination of my academic efforts but a collective outcome made possible through the contributions of many individuals. To all those who supported me directly or indirectly—thank you from the bottom of my heart.

Ar. Neeraj Kumar Kushwaha

Masters in Urban Planning BBDU,

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ABSTRACT

This thesis titled “Circular Economy Models in Urban Solid Waste Management” is the culmination of my academic journey as a student of the Master of Planning (Urban Planning), IV Semester, for the academic year 2024–25. The research explores the critical transition needed in Indian urban waste systems—from linear “collect and dispose” approaches to circular models that emphasize resource efficiency, sustainability, and inclusivity.

The focus area of this study is Lucknow, with special attention to Zones 5 (Alambagh) and 8 (Ashiyana–Vrindavan Yojna). These zones were selected due to their dense population, mixed-income settlements, existing waste challenges, and potential for scalable circular interventions. The research seeks to contribute toward sustainable urban waste governance by aligning with national missions such as Swachh Bharat Mission (SBM-U 2.0), Smart City Mission, Atmanirbhar Bharat, and the UN Sustainable Development Goals (SDGs 11 & 12).

The core objective is to develop a city-specific, circular economy-based framework for solid waste management. A mixed-methods approach was adopted, including primary data collection (household surveys, stakeholder interviews, waste audits) and secondary data review (municipal records, policy documents, global case studies). Comparative insights were drawn from successful models in Indore, Pune, and international cities like Norway, to benchmark best practices.

This study also applies the Kano Model to evaluate user satisfaction with 26 proposed waste service features, classifying them into Must-be, Performance, Attractive, and other categories. The analysis revealed strong public support for decentralized composting, door-to-door collection, waste-to-energy technologies, and citizen incentives—underscoring the value of community engagement and responsive systems.

An integrated incentive-based policy framework has been proposed to guide implementation. It covers citizens, informal sector workers, municipal bodies, private investors, and startups, supported by digitalization and smart governance tools.

I sincerely hope that the insights, framework, and recommendations presented in this thesis will serve as a valuable resource for urban planners, policymakers, municipal administrators, and researchers working toward waste sustainability in medium and large Indian cities.

This work is dedicated to the cause of building cleaner, greener, and more resilient urban futures.

Keywords- Circular Economy, Urban SWM, Kano Model, UN SDG’s- 11&12, Incentive-Based Policy Framework

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Chapter 1 - Introduction

1.1 Background

Urban solid waste management (SWM) in rapidly urbanizing cities like Lucknow presents significant challenges. Traditional linear models—“take-make-dispose”—have led to overflowing landfills, environmental pollution, and resource depletion. In contrast, the circular economy (CE) approach emphasizes waste prevention, resource recovery, and closed-loop systems that maximize material reuse and recycling.

1.2 Circular Economy Initiatives in Lucknow

In response to these challenges, the Lucknow Municipal Corporation (LMC) has initiated steps towards adopting circular economy principles. Drawing inspiration from Indore's successful waste management model, LMC plans to treat biodegradable waste at the source, such as in hostels, hotels, and residential areas, by installing composters. This initiative aims to reduce daily waste generation by 300 metric tons and decrease the number of dumpers transporting waste to treatment plants .

Additionally, the LMC is promoting waste segregation among residents by encouraging the use of separate bins for biodegradable and non-biodegradable waste. This approach aligns with the principles of the circular economy by facilitating recycling and reducing landfill dependency.

1.3 Alambagh: A Case Study for Circular Economy Implementation

Alambagh, a densely populated residential area in Lucknow, exemplifies the challenges and potential for implementing circular economy models in urban waste management. The area's high population density contributes to substantial waste generation, necessitating effective waste management strategies.

Applying circular economy principles in Alambagh could involve:

- **Community-Based Composting**: Encouraging residents to compost organic waste at the household or community level to reduce biodegradable waste sent to landfills.
- **Recycling Initiatives**: Establishing local recycling centers to process non-biodegradable materials, promoting material recovery and reducing environmental impact.

- **Awareness Campaigns**: Conducting educational programs to inform residents about the benefits of waste segregation and recycling, fostering a culture of sustainability.

Implementing these strategies in Alambagh could serve as a model for other urban areas in Lucknow, demonstrating the feasibility and benefits of circular economy approaches in urban waste management.

Figure 1.1 : CE in Urban SWM

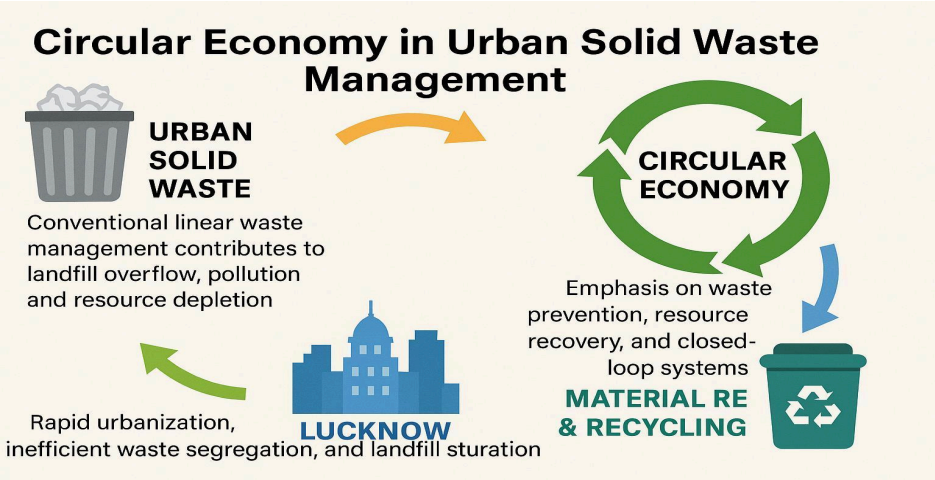

Figure 1.2 : Problem statement Graphical representation

1.4 Significance of the Study:

This research holds critical significance in guiding the transformation of Lucknow's urban solid waste management system by aligning it with circular economy (CE) principles. By focusing on Alambagh—a high-density urban locality—it offers insights into practical, community-centered interventions that can be scaled city-wide. The study aims to inform urban policy by highlighting the benefits of decentralized waste

processing units, such as composting and localized recycling hubs, which reduce pressure on central landfills. It also underscores the importance of integrating smart waste technologies for efficient collection, segregation, and tracking of municipal solid waste (MSW). Furthermore, the research will explore the role of public-private partnerships (PPPs) in building sustainable waste infrastructure and ensuring long-term operational viability. Overall, the findings will serve as a strategic roadmap for municipal authorities, urban planners, and policymakers, helping Lucknow transition toward a zero-waste future while improving environmental quality, public health, and resource efficiency through inclusive and adaptive CE models.

Figure 1.3 : Strategies to mitigate 3 R's

Chapter 2 - Aim & Objectives

2.1 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.

Figure 2.1 : CE Based Framework

2.2 Objectives:

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.

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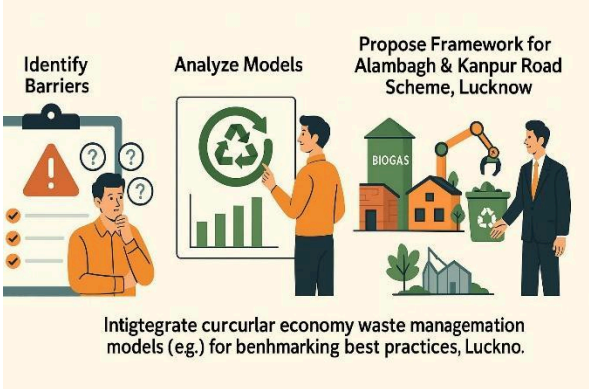
Figure 2.2 : Graphical Representation of Objectives



2.3 Research Questions

A. Primary Research Question:

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

Figure 2.3 : LMC Transition to CE

B. Secondary Research Questions:

- What policy interventions and financial incentives are necessary for Lucknow to adopt a circular waste management system?

Figure 2.4 : Policy & Incentives Graphical Representation

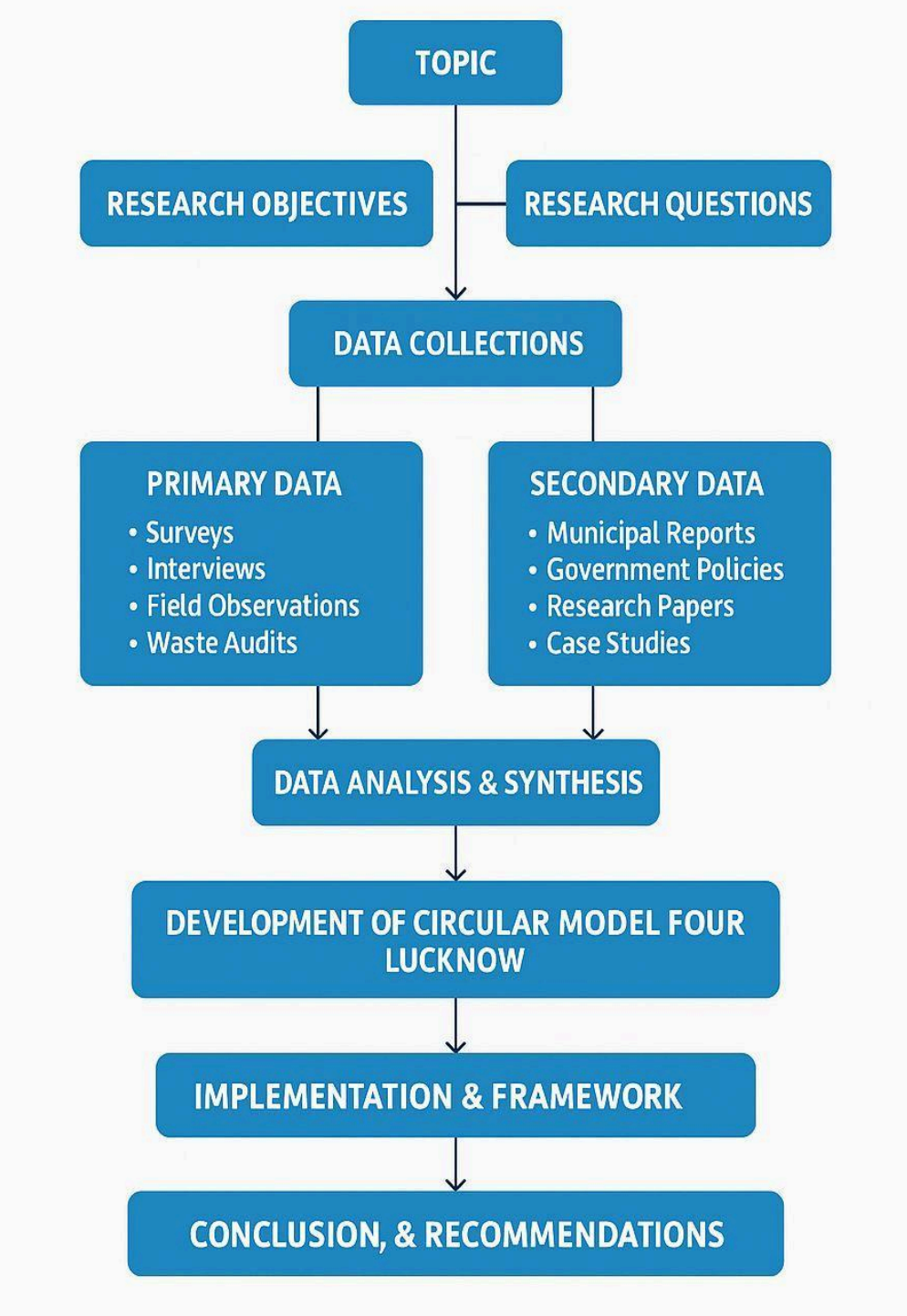
- How can smart technologies (AI, IoT, blockchain) improve waste collection, sorting, and recycling efficiency?

Figure 2.5 : Use of AI, IoT, Blockchain

Chapter 3 - Detailed Methodology

This research employs a mixed-methods approach, integrating qualitative and quantitative data to analyze waste management patterns, stakeholder perspectives, and technological feasibility.

Figure 3.1 : Methodology Flow Chart



1. Topic

The present research is titled 'Circular Economy Models in Urban Solid Waste Management'. The study is focused on exploring the integration of circular economy principles in the context of urban solid waste management, with specific reference to the city of Lucknow.

2. Research Objectives and Research Questions

The research is guided by a set of well-defined objectives and research questions that outline its scope and direction. While the objectives describe the intended outcomes, the research questions highlight the specific areas of inquiry. Both components have been formulated in parallel and serve as the foundation for the data collection and analysis process.

3. Data Collection

This phase involves the empirical gathering of data required to answer the research questions and achieve the stated objectives. Data has been collected from both primary and secondary sources:

• Primary Data: Includes surveys, structured interviews, direct field observations, and waste characterization audits.
• Secondary Data: Comprises official municipal reports, government policy documents, academic research publications, and relevant case studies.

4. Data Analysis and Synthesis

Following data collection, the information is processed and analyzed. This involves the cleaning, categorization, and interpretation of data to identify key trends, challenges, and opportunities. The comparative assessment and synthesis of primary and secondary data enable the formulation of actionable insights.

5. Development of a Circular Economy Model for Lucknow

Based on the analytical findings, a city-specific model for circular waste management is proposed. The model incorporates components such as:
• Application of smart waste technologies,
• Establishment of decentralized composting and biogas units,
• Integration of informal waste workers into formal systems,
• Creation of public-private partnership (PPP) frameworks.

This model is contextualized for the urban characteristics and socio-economic realities of Lucknow.

6. Implementation Strategy and Framework

In this stage, the proposed model is translated into an actionable strategy. This includes defining stakeholder responsibilities, implementation phases, and policy guidelines. Technical and institutional frameworks are also proposed to facilitate systematic adoption.

7. Conclusion and Recommendations

The final stage of the research summarizes the key findings, identifies persistent challenges, and offers evidence-based recommendations. These encompass policy directives, infrastructural innovations, and community engagement strategies to promote the adoption of circular economy-based solid waste management systems in Lucknow and similar urban centers.

Summary

This methodology provides a comprehensive and systematic approach to address the challenges of urban solid waste through the lens of the circular economy. It ensures academic rigor while offering practical strategies that can be employed by policymakers, planners, and civic bodies.

Types of Data & Collection Methods:

Table 3.1 : Data Type & Collection Methods

Data Type	Collection Methods	Purpose
Primary Data	Surveys, Interviews, Field Observations, Waste Audits	To collect fist-hand data on waste segregation, recycling behaviors, and municipal operations.
Secondary Data	Municipal Reports, Government Policies, Research papers, Case Studies	To analyze existing waste management policies, technological innovations, and global best practices.

3.1 Summary of Data Collection & Analysis Methods

Table 3.2 :Summary of Data Collection & Analysis Methods

Method	Target Group	Purpose
Household & Business Surveys	500+Households, 100+ Business in Alambagh	Assess waste generation patterns & community awareness.
Stakeholder Interviews	Municipal Officers ,Waste Workers ,Recycling Firms,NGOs	Understand policy gaps & infrastructure challenges.
Field Observations	Bhauli Landfill, Composting Units, Transfer Stations	Document waste processing efficiency & resource recovery potential.
Comparative Case Study Analysis	Indore , Mysuru ,Global Cities	Identify best practices for circular waste models.
Smart Waste Tech Providers	Smart Waste Tech Providers	Evaluate AI, IoT , Blockchain use in waste management .

3.2 Scope & Limitations of the Study

Scope:

1. Focuses on Lucknow's municipal solid waste system, with a pilot study in Alambagh.
2. Analyzes policy, technology, and infrastructure for circular economy implementation.
3. Includes comparative analysis of national & international best practices.
4. Proposes a scalable circular economy model that can be implemented across 10 Million + cities.

Limitations:

1. Geographical limitations
2. Time constraints may limit the depth of primary data collection.
3. Limited funding for smart waste technology testing in the pilot phase.
4. Stakeholder engagement (municipal, corporate, informal workers) may face resistance due to existing operational structures.

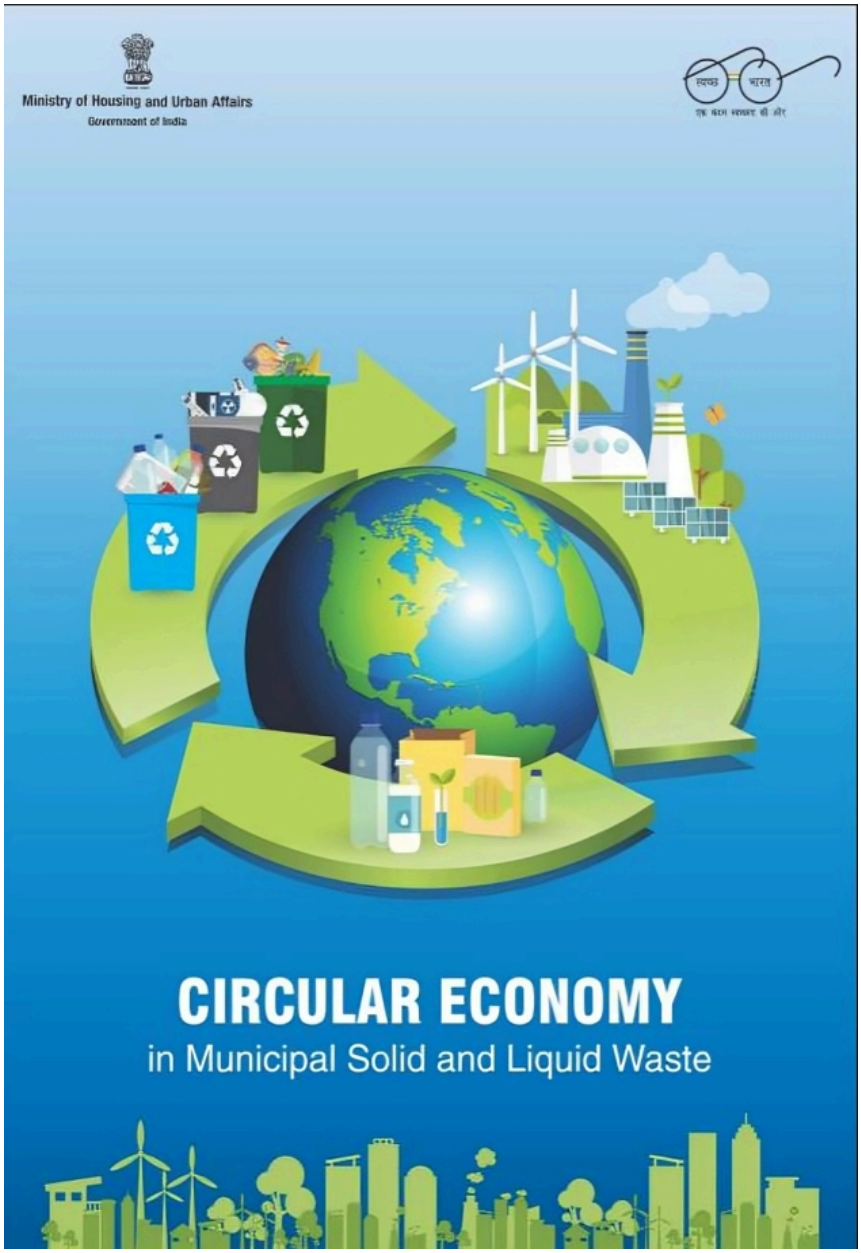
Chapter 4 - Literature Study

4.1 Title- "Framework for Transitioning Indian Cities to Circular Economy Waste Models"

Published by: **Ministry of Housing and Urban Affairs (MoHUA), Government of India**

Year: **2021**

Figure 4.1: Cover page of the report "Framework for Transitioning Indian Cities to Circular Economy Waste Models"



Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

1. Objective

To provide a comprehensive, actionable framework that guides Indian cities in transitioning from linear to circular solid waste management models,

Thereby, promoting sustainability, resource efficiency, and economic resilience.

2. Background Context

- India generates over 62 million tons of waste annually, and this is expected to increase significantly.
- Current waste management practices are largely linear: collection, transportation, landfilling.
- The circular economy (CE) model emphasizes reduce, reuse, recycle (3Rs), with a focus on keeping resources in use for as long as possible.

3. Methodology

- Compilation and review of successful international and Indian case studies.
- Stakeholder consultations with urban local bodies (ULBs), NGOs, and private sector.
- Analytical modeling and framework development using systems thinking and circular economy principles.

4. Key Components of the Framework

a. Enabling Policies

- Integration of CE in *City Sanitation Plans (CSPs)* and *Smart City initiatives*.
- Use of *Extended Producer Responsibility (EPR)* in plastics and e-waste management.

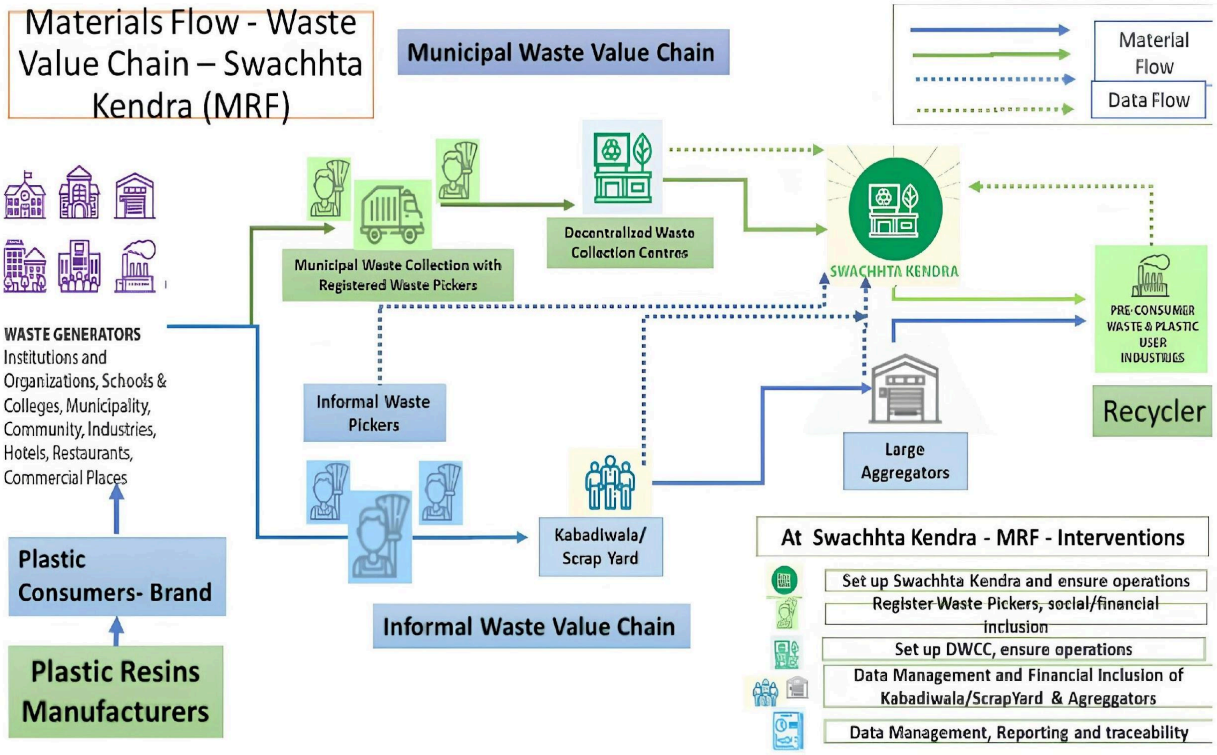
b. Institutional Framework

- Strengthening **ULBs** with training, digital platforms, and decentralized waste management models.
- Establishment of **Material Recovery Facilities (MRFs)** and **Composting Units** at the ward or cluster level.

c. Economic Instruments

- Incentives for waste segregation, composting, and recycling.
- Promotion of green jobs and circular entrepreneurship, particularly in the informal sector.

Figure 4.2: Material flows in the plastic waste value chain system

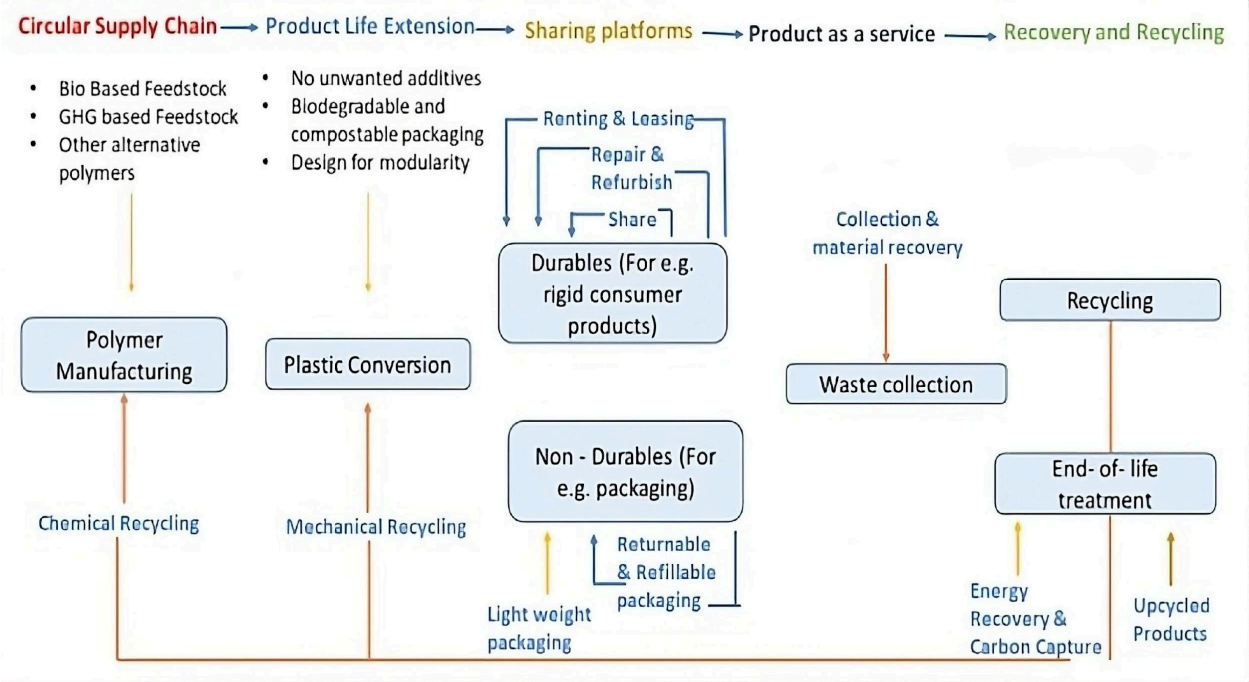


Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

Figure 4.3: Annual Per Capita Plastic Consumption

Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

Figure 4.4: Circular Economy Business models in Plastics Value Chain



Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

Table 4.5: C&D waste generation with respect to population categories

Sr. No.	Population Categories	C & D waste Generation
1	More than 10 million	Approximately 25% of the Total solid waste generated
2	1-10 million	20-25% OF THE Total solid waste generated
3	0.5-1 million	15-20% of the total solid waste generated
4	Less than 0.5 million	10% of the total solid waste generated

Figure 4.5: Municipal Solid Waste Composition

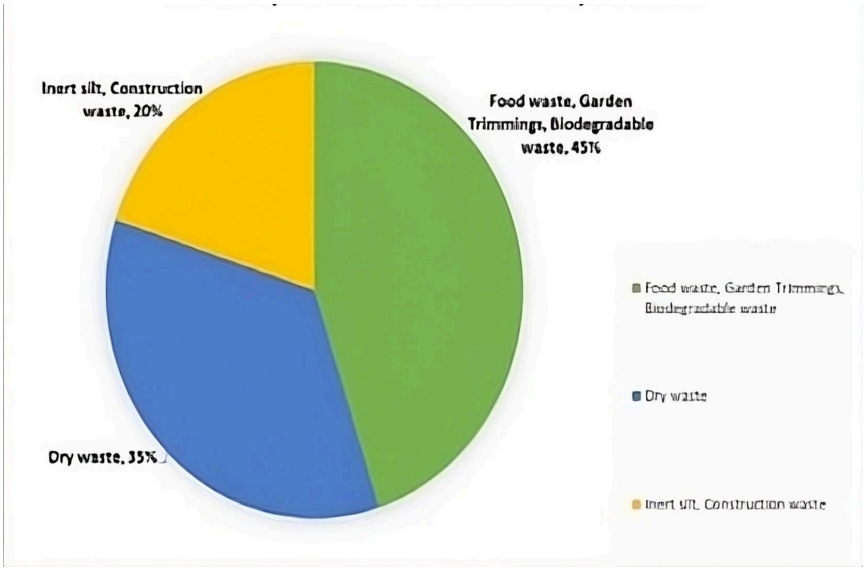
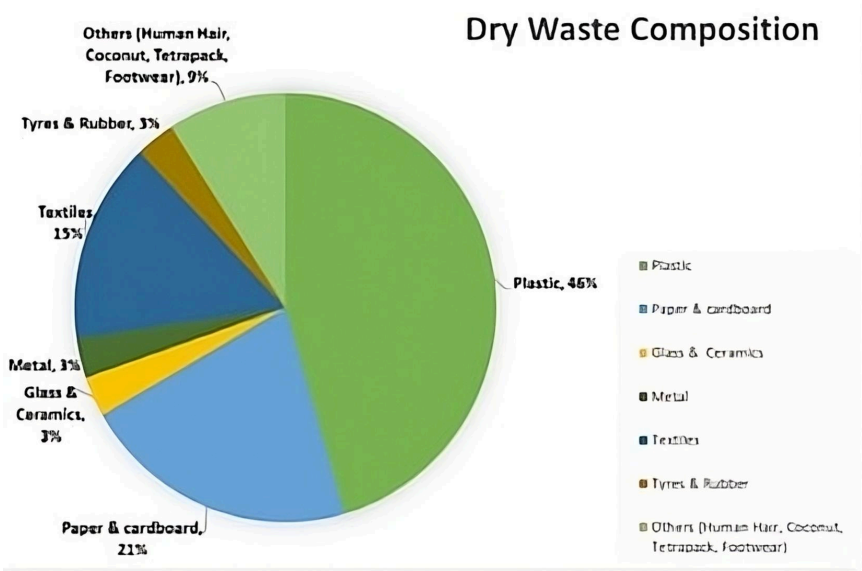


Figure 4.6: Dry Waste Composition in MSW



Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

d. Community Engagement

- Behavior change campaigns (e.g., *Swachh Bharat Mission* continuation).
- School-based and community-based waste literacy programs.

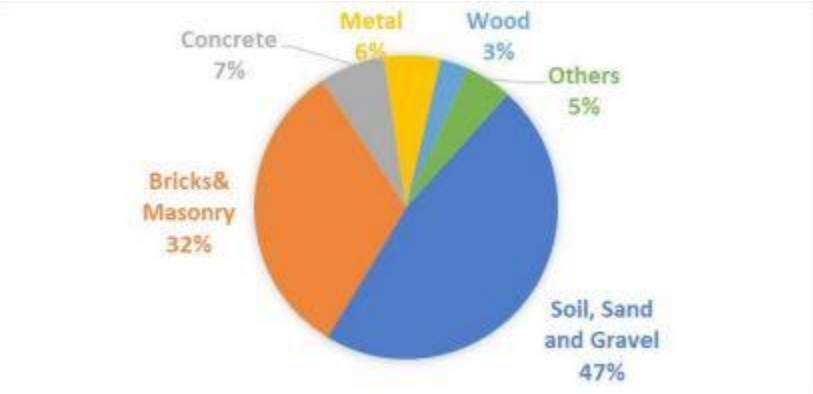
5. Highlights / Innovations

- Emphasis on **data-driven governance** and digital platforms for waste tracking.
- Proposal for a **Waste to Wealth** roadmap aligning with India's **Atmanirbhar**

Bharat vision.

- Encourages use of **Public-Private Partnerships (PPPs)** in setting up CE infrastructure.

- **Figure 4.7: Construction Waste Composition in MSW**



Source : Report **"Framework for Transitioning Indian Cities to Circular Economy Waste Models"- by MoHUA**

6. Challenges Addressed

- Lack of segregation at source.
- Weak institutional capacity in smaller towns.
- Absence of market linkages for recyclables and compost.
- Resistance from the informal sector due to fear of livelihood loss.

7. Recommendations

- Develop a **national dashboard** for CE performance monitoring.
- Foster **inter-city collaboration** and knowledge exchange.
- Institutionalize **Circular Economy Cells** within city governance structures.
- Strengthen **R&D and innovation** through tie-ups with academic institutions and startups.

8. Strengths of the Report

- Clear action-oriented roadmap.
- Aligns with global best practices and India's national missions (AMRUT, SBM, SDGs).
- Recognizes the importance of inclusivity (informal sector, women).

9. Limitations / Gaps

- Lacks concrete funding mechanisms or detailed financial models.

- Monitoring and evaluation tools are not fully developed.
- Applicability to smaller towns with limited administrative capacity is weakly addressed.

10. Conclusion

The **MoHUA (2021)** report serves as a milestone document in India's transition toward sustainable urban waste management. It offers a practical, scalable framework to integrate **circular economy principles** into policy and practice but requires strong political will, financial backing, and community participation for successful implementation.

4.2 Title-“Toward Zero-Waste Cities: Comparative Study”

Year: 2024

Focus: Case studies of Indore, Pune, and select global zero-waste cities

1. Objective

To examine the strategies, policies, and practical models adopted by leading Indian cities (Indore and Pune) and global counterparts (such as San Francisco, Ljubljana, and Tokyo) to move toward **zero-waste goals**, identifying common success factors and challenges.

2. Research Questions

- What policy frameworks and operational models have enabled successful waste reduction in these cities?
- What role does community participation, governance, and technology play in achieving zero-waste targets?
- How can Indian cities replicate or adapt global best practices?

3. Methodology

- **Comparative case study analysis** using qualitative and quantitative data.
- **Field visits**, interviews with municipal officers, waste entrepreneurs, and citizen groups.
- Review of **municipal records**, **Swachh Bharat rankings**, and **global zero-waste benchmarks**.

4. Case Study Insights

Indore

- ***Achievements:*** India’s cleanest city (multiple SBM rankings), 100% door-to-door collection, waste segregation at source.
- ***Innovations:*** Bio-CNG plant (processing 550 tons/day), use of GPS for vehicle tracking, revenue from recyclables.
- ***Community Role:*** Resident Welfare Associations, Swachhata Doots, regular awareness drives.

Figure 4.8 : Door To door Segregation & collection Indore

Source: IMC

Pune

- ***Achievements:*** Strong informal sector integration through SWaCH Cooperative.
- ***Innovations:*** User fee system, decentralized composting, dry waste collection centers.
- ***Strength:*** Cooperative model for waste pickers, gender inclusion, door-to-door waste service expansion

Figure 4.9 : Decentralized Composting in Pune

Source: IMC

Global Examples

San Francisco (USA)

- 80% waste diversion rate through 3-bin system.
- Mandatory composting and recycling.
- Strong enforcement and public participation.

Figure 4.10 : 3 Bin system San Francisco

Source : San Francisco Environment department

Ljubljana (Slovenia)

- First EU capital to adopt zero-waste strategy.
- Extensive citizen education and waste separation programs.
- Emphasis on reuse and community repair centers.

Tokyo (Japan)

- Detailed 45-category waste separation system.
- Emphasis on producer responsibility and zero landfill usage.

5. Comparative Framework

Table 4.1 : 3 Comparative Analysis

Criteria	Indore	Pune	Global Cities
Segregation at Source	Yes	Yes	Yes (strictly enforced)
Informal Sector	Moderate	Strong	Varies

Integration			
Decentralized Waste Systems	Moderate	Strong	Strong
Public Awareness Campaigns	High	Moderate	Very High
Legislative Support	SBM & local	SBM & local	Comprehensive city laws
Composting & Resource Recovery	Yes	Yes	Advanced

Figure 4.11 : Recycle Trash Bin in Ljubljana (Slovenia)

Figure 4.12 : Segregation & Incineration in Ljubljana (Slovenia)

Source : Ljubljana Environment Department (Slovenia)

6. Strengths of the Paper

- Practical and up-to-date comparisons.
- Use of real metrics (e.g., diversion rate, compost output).
- Emphasis on **replicability** in Indian urban contexts.

7. Limitations

- Limited inclusion of smaller or less-resourced cities.
- Financial cost-benefit analysis not deeply explored.
- Behavioral change measurement methods are not well elaborated.

8. Key Recommendations

- Cities must adopt a **phased approach** with measurable milestones.
- **The informal sector** should be formalized and supported.
- Invest in **capacity-building** for municipal staff.
- Promote **decentralized waste treatment systems** at ward level.
- Strengthen **policy enforcement** and public accountability.

9. Conclusion

The paper showcases how Indian cities like Indore and Pune are paving the way toward zero-waste, with significant progress rooted in innovation, public participation, and strong local governance. The comparative lens with global cities helps identify scalable models and reveals that while context-specific challenges exist, **political will**, **community engagement**, and **technological integration** remain the backbone of any successful zero-waste strategy.

4.3 Title :*"Driving Sustainability: Circular Economy in Waste Management (2021)"*

1. Definition and Objectives

Circular Economy in Waste Management is a restorative system that aims to:

Eliminate Waste: Design products and processes to minimize waste generation.

Circulate Resources: Maintain the value of products, materials, and resources in the economy for as long as possible.

Regenerate Nature: Support natural systems and processes to restore and renew resources.

2. Origins and Influences

The circular economy model draws inspiration from global sustainability frameworks and India's commitment to achieving the Sustainable Development Goals (SDGs). Influential policies include the **Swachh Bharat Mission-Urban 2.0** and the **GOBARdhan scheme**, which aim to promote waste-to-wealth initiatives and sustainable waste management practices.

Figure 4.13 : Swachh Bharat Mission 2.0

Source : SBM website

3. Key Components

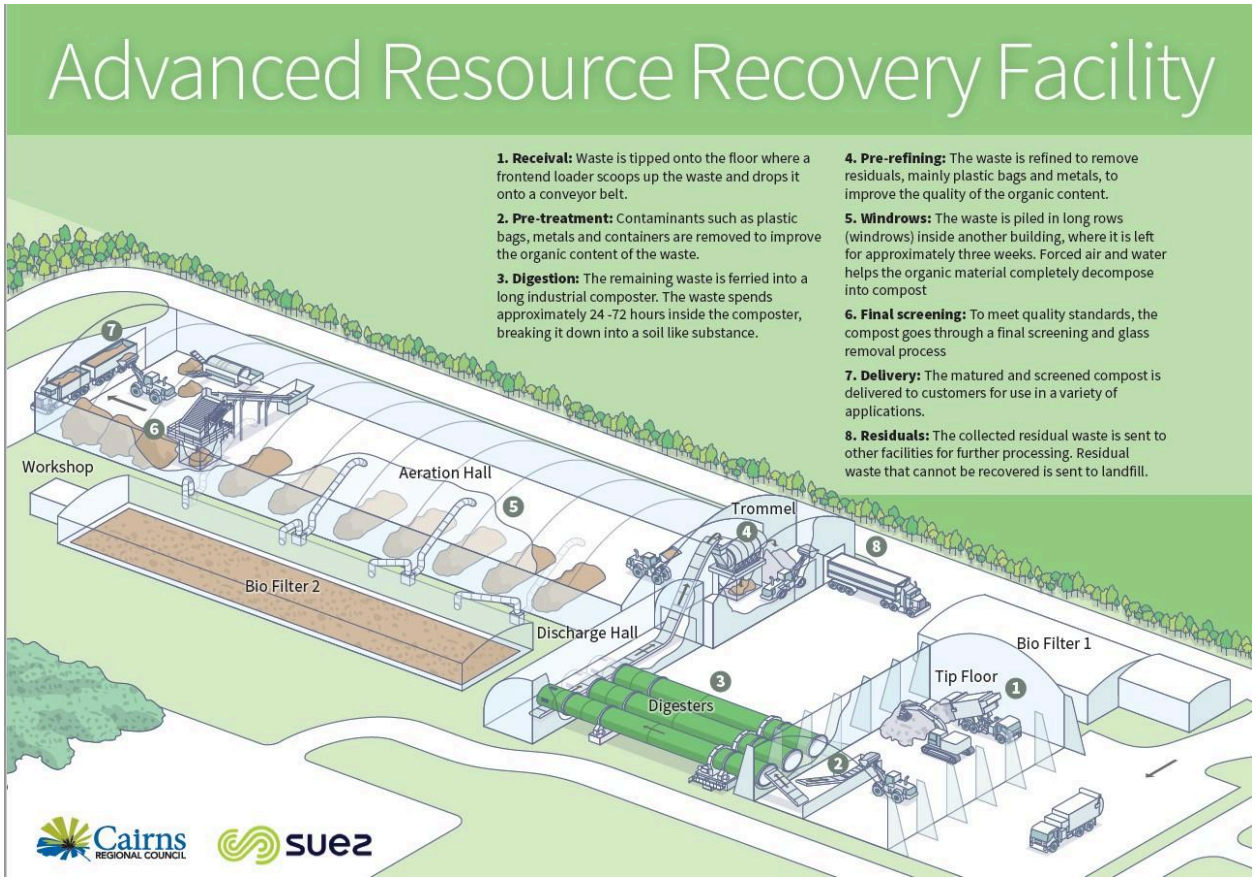
The framework encompasses several critical components:

- **Waste Segregation**: Implementing source segregation to facilitate recycling and

composting.

- **Resource Recovery Facilities**: Establishing bio-methanation and waste-to-energy plants to process organic and dry waste.
- **Policy and Regulatory Support**: Developing standards and incentives to encourage CE.
- **Capacity Building**: Training urban local bodies and stakeholders in CE principles and practices.

Figure 4.13 : Advanced Resource Recovery Facility



Source : Cairns Regional Council

4. Global Implementations

Internationally, cities like **Amsterdam** and **Tokyo** have successfully integrated circular economy principles into their waste management systems. These cities have demonstrated effective models of waste segregation, resource recovery, and public-private partnerships that India aims to emulate.

Recommendations

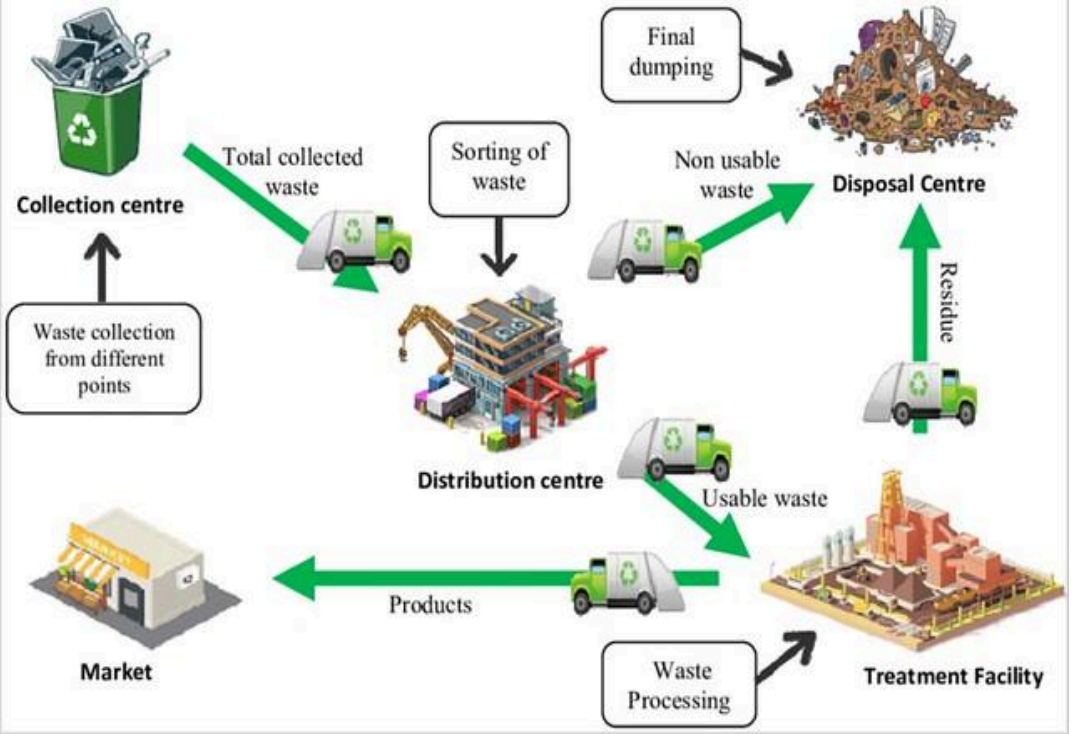
- **Adopt a Holistic Circular Economy Policy Framework**
    - Integrate CE principles across all urban waste management policies.
    - Ensure policy alignment with national missions like SBM 2.0, AMRUT, and SDGs.
- **Strengthen Source Segregation Mechanisms**
    - Make household-level waste segregation mandatory.
    - Provide standardized color-coded bins and regular training to households.

Figure 4.14 : Source Segregation Mechanism

Source : greensutra.in

- **Promote Decentralized Waste Processing Units**
    - Establish composting, bio methanation, and recycling units at ward or community level.
    - Reduce dependency on large centralized facilities.

Figure 4.15 : Decentralized Waste Processing Units



Source : Cairns Regional Council

- **Formalize the Informal Waste Sector**
    - Recognize and integrate waste pickers into the municipal framework.
    - Provide social security benefits, ID cards, and capacity-building programs.
- **Use Economic Instruments**
    - Introduce user fees, polluter-pays principle, and incentives for waste reduction and segregation.
    - Support startups and MSMEs working in recycling and upcycling.
- **Public Awareness and Behavioral Change Campaigns**
    - Run long-term IEC (Information, Education & Communication) campaigns.
    - Engage schools, resident welfare associations, and local influencers.
- **Digitalization and Real-Time Monitoring**
    - Use GPS, RFID, and mobile apps to monitor collection and processing.

- Build city-level waste dashboards for transparency and decision-making.

- **Capacity Building and Training of ULBs**

    - To implement circular economy practices effectively, the thesis recommends providing technical training and dedicated funding to Urban Local Bodies (ULBs), enhancing their capacity for infrastructure development, policy execution, and stakeholder coordination.

GAPS IDENTIFIED

- **Policy-Implementation Mismatch**

    - National and state-level CE policies lack proper execution at city and ward levels.

    - Weak enforcement of waste segregation rules.

- **Lack of Reliable Data**

    - Absence of city-level data on waste generation, composition, and material flows hinders effective planning.

- **Limited Financial Support**

    - Circular economy models in urban solid waste management, municipalities often struggle with funding constraints, limiting their ability to invest in essential infrastructure and technologies. This financial barrier hinders effective implementation, scalability, and long-term sustainability of CE initiatives.

- **Neglect of Informal Sector**

    - Circular economy-based waste management, informal workers play a vital role in recycling but often lack formal recognition, social security, and integration, limiting their contribution to a sustainable and inclusive system.

- **One-size-fits-all Approach**

    - Uniform CE policies may not suit small towns or peri-urban areas with different challenges.

- **Technology Lock-In Risk**

    - Overreliance on large-scale incinerators and centralized waste-to-energy plants could undermine CE goals if not backed by segregation and recovery.

- **Public Resistance**

    - Circular economy-based urban solid waste management, low citizen participation stems from inadequate awareness campaigns and lack of continuous engagement, weakening source segregation, recycling efforts, and community-driven sustainability initiatives.

4.4 Title :*“Transitioning Indian Cities into Circular Economy (2022): Challenges in Municipal Solid Waste Governance”*

1. Definition and Objectives

Circular Economy in Urban Waste Management: A circular economy in the context of urban solid waste management refers to a systemic approach that prioritizes the reduction, reuse, and recycling of materials, aiming to minimize waste generation and resource consumption.

Key Objectives:

Enhance resource efficiency and reduce dependency on virgin materials.

Promote sustainable waste management practices to minimize landfill usage.

Encourage community participation and behavioral change towards waste segregation and recycling.

Foster innovation in waste processing technologies and business models.

2. Origins and Influences

Global Influences:

The concept of a circular economy has been influenced by various global frameworks and initiatives, including the European Union's Circular Economy Action Plan and the United Nations' Sustainable Development Goals, which emphasize sustainable consumption and production patterns.

Indian Context:

In India, the transition towards a circular economy in urban waste management has been propelled by national policies such as the Swachh Bharat Mission-Urban (SBM-U), which aims to create garbage-free cities through improved waste processing and recycling.

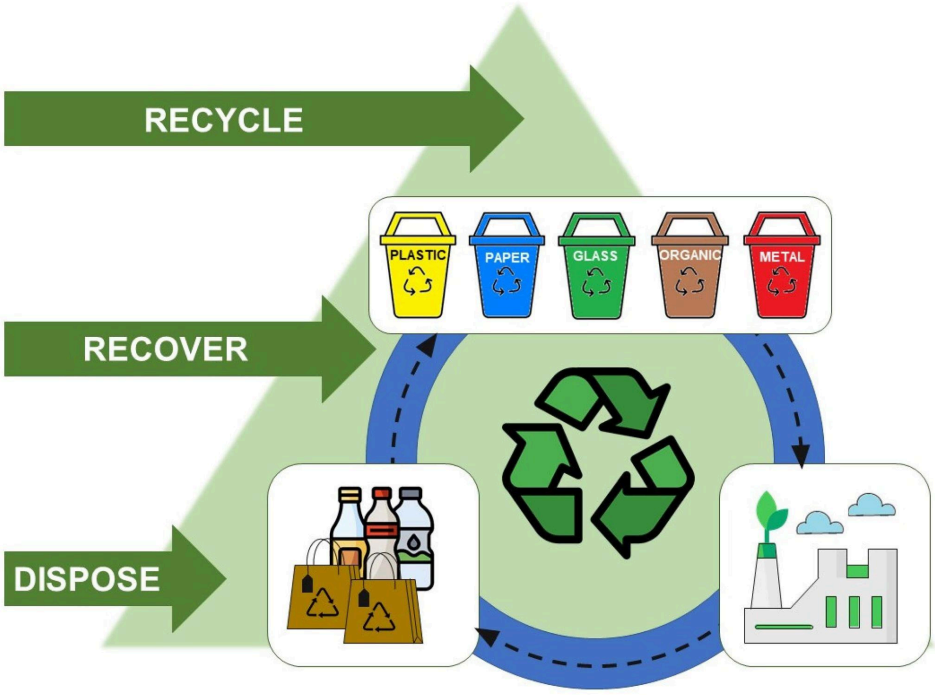
The government has also initiated the GOBARdhan scheme to establish 500 Waste to Wealth plants, promoting the conversion of organic waste into biogas and compost.

3. Key Components

Waste Segregation: Implementing systems for separating waste at the source into categories like biodegradable, recyclable, and non-recyclable to facilitate efficient processing.

Recycling and Processing Infrastructure: Developing facilities such as Material Recovery Facilities (MRFs), composting units, and waste-to-energy plants to process segregated waste.

Figure 4.16 : 3 R's and Process



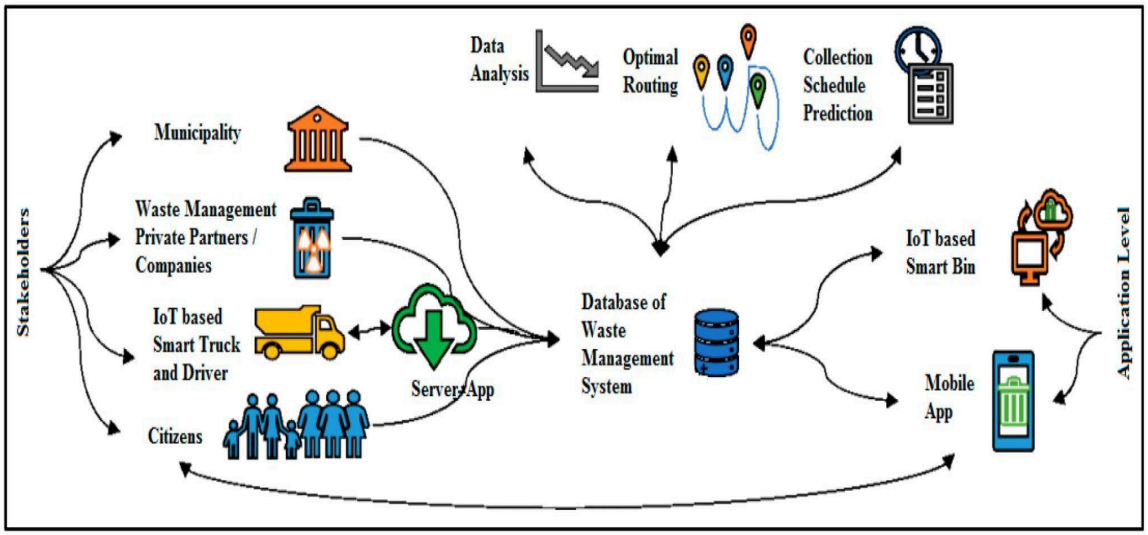
Source : MDPI Journals

Policy and Regulation: Enforcing policies like Extended Producer Responsibility (EPR) and Plastic Waste Management Rules to hold producers accountable for the lifecycle of their products.

Community Engagement: Educating and involving citizens in waste management practices through awareness campaigns and incentive programs.

Technology Integration: Utilizing digital platforms and data analytics to monitor waste generation, collection, and processing, enhancing efficiency and transparency.

Figure 4.17 : Technological Integration in SWM



Source : MDPI Journal

Recommendations

Strengthen Urban Local Bodies (ULBs)

Decentralize governance and empower ULBs with greater autonomy and financial resources to implement circular economy (CE) strategies.

Develop City-Specific Circular Economy Roadmaps

Customize CE frameworks based on local waste composition, urban form, and community behavior.

Prioritize ward-level planning and localized solutions.

Institutional Integration and Coordination

Create coordination mechanisms between urban development authorities, pollution boards, and municipal departments.

Form dedicated CE cells within ULBs.

Legal and Regulatory Reforms

Introduce enforceable city-level CE mandates.

Strengthen monitoring and penal provisions for non-compliance in waste segregation and processing.

Private Sector and Startup Engagement

Encourage PPP (Public-Private Partnerships) for waste processing, recycling, and innovation.

Incubate and support CE-based startups through municipal innovation cells.

Capacity Building and Skill Development

Train municipal staff, sanitation workers, and informal waste collectors in CE techniques and technologies.

Enhanced Community Engagement

Foster behavioral change through targeted IEC (Information, Education, Communication) campaigns.

Recognize and incentivize active community and RWA participation.

Technology and Data-Driven Planning

Use IoT, GIS, and AI tools to track waste flow and optimize collection systems.

Establish material flow accounting systems.

Gaps Identified

Institutional Fragmentation

Waste governance is divided among multiple agencies, leading to overlap, inefficiency, and lack of accountability.

Weak Monitoring and Enforcement

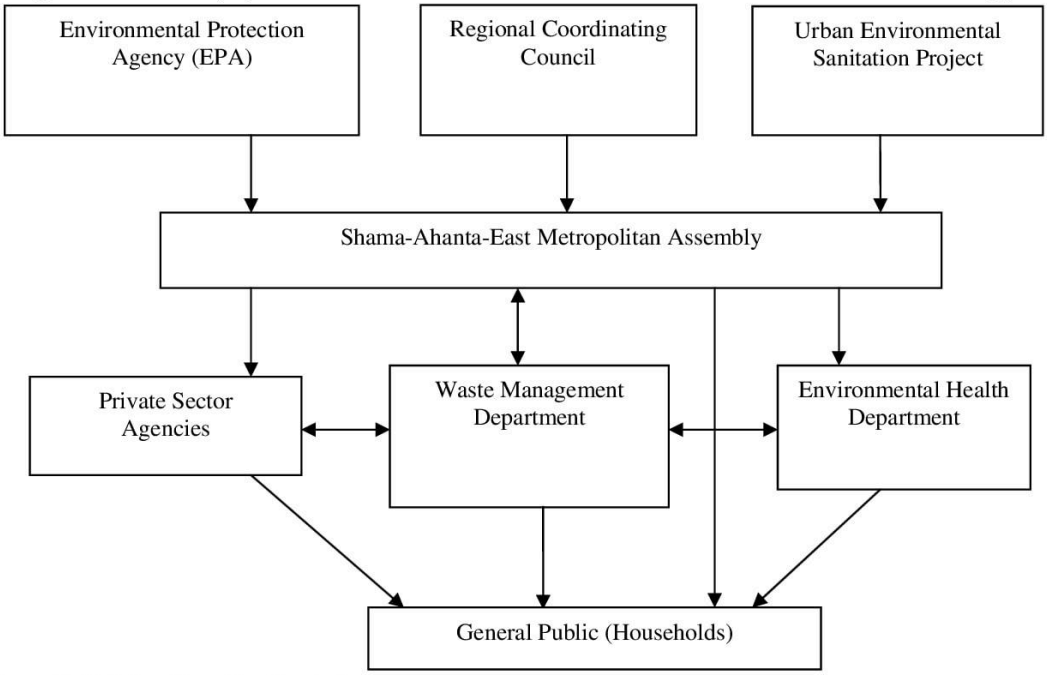
Poor enforcement of existing waste management rules, especially in tier-2 and tier-3 cities.

Limited Public Awareness

Citizens often lack understanding or motivation to engage in source segregation

and CE activities.

Figure 4.18 : Technological Integration in SWM



Source - www.SemanticScholar.com

Absence of CE Metrics and Indicators

No standardized indicators or reporting frameworks to assess a city's circularity or waste diversion success.

Insufficient Funding Mechanisms

ULBs lack stable and adequate financial resources for infrastructure, technology adoption, and operational sustainability.

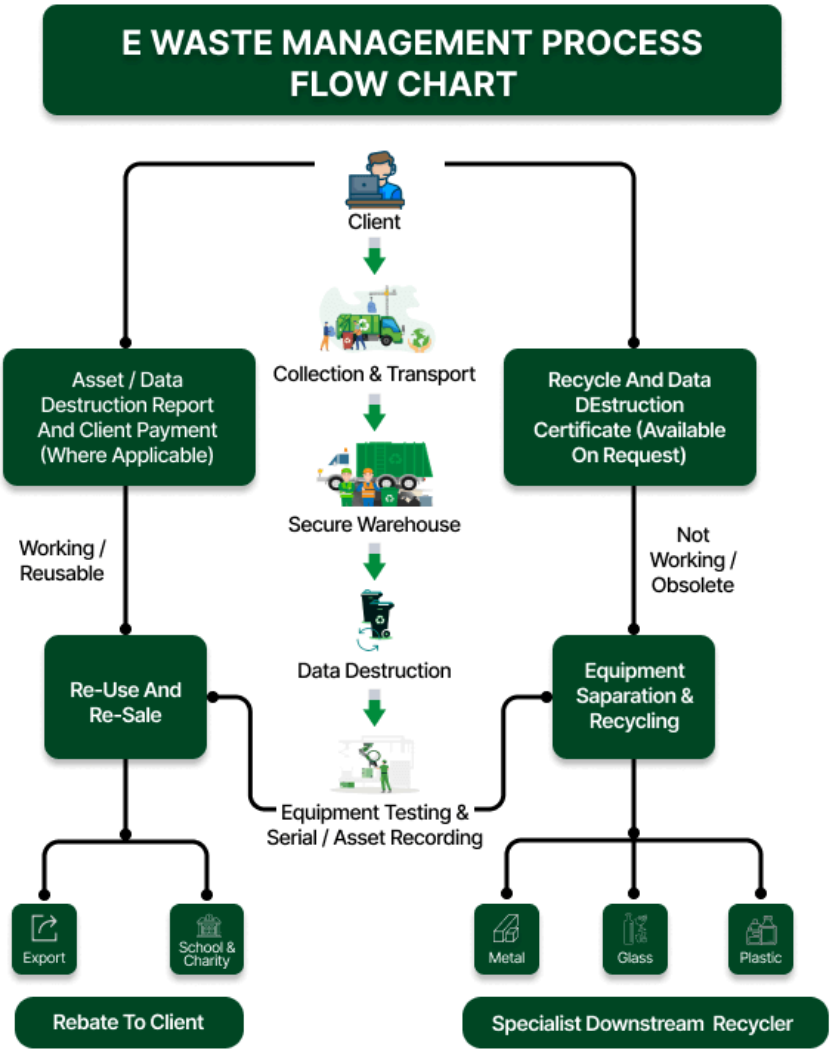
Neglect of Informal Sector Contributions

Informal waste workers remain unrecognized in CE planning, though they handle a significant share of recyclables.

Top-Down Implementation Models

CE programs are often implemented without enough consultation with local communities or stakeholders, resulting in low ownership and sustainability.

Figure 4.20 : Waste Management Process Flow Chart



Source - www.sswml.com

Chapter 5 - Case Study

5.1 Case Study 1: Indore, Madhya Pradesh

Title: India's Cleanest City – A Model for Circular Economy in Solid Waste Management

1. Introduction

Indore, the commercial capital of Madhya Pradesh, has emerged as India's cleanest city for six consecutive years (2017–2022) under the **Swachh Survekshan rankings**. Its transformation into a circular economy-driven waste management model offers a benchmark for urban sustainability in Indian cities.

2. Background

Population: ~3.5 million (as per 2021 estimates)

Waste Generation: Approx. 1,200–1,500 tons/day

Key Challenge (Pre-2016): Open dumping, unsegregated waste, poor public participation, and legacy waste heaps at dumpsites like Devguradia.

3. Key Interventions

Circular Economy Approaches Implemented :

Table 5.1 Key Interventions

Domain	Intervention Type
Source Segregation	100% door-to-door collection with 6 types of waste segregation (wet, dry, sanitary, etc.)
Decentralized Systems	Composting units and MRFs (Material Recovery Facilities) in all 85 wards
Bio-CNG Production	Asia's largest Bio-CNG plant processing 550 TPD of wet waste, generating gas used by city buses
Plastic Waste	Tie-ups with cement plants for co-processing non-recyclable plastic

Digital Governance	GPS-fitted vehicles, mobile apps for real-time monitoring, “Indore 311” complaint system

4. Governance and Community Participation

- Led by **Indore Municipal Corporation (IMC)** with strong political will and IAS-led administrative backing.
- Intensive **IEC campaigns**, Swachhata Doots (sanitation workers), and community influencers played a critical role.

Waste pickers organized into **SHGs and cooperatives**, reducing exploitation and improving livelihoods.

5. Outcomes & Impact

Table 5.2 Outcomes & Impact

Impact Area	Result
Cleanliness Ranking	Rank #1 in Swachh Survekshan (2017 to 2022)
Landfill Dependency	Zero landfill city as of 2022
Resource Recovery	Over 90% waste diverted from landfill; compost and recyclables sold
Bio-CNG Output	17,000–18,000 kg/day; used in city buses and for municipal uses
Employment Generation	Thousands of jobs in collection, composting, MRFs, SHGs
Revenue Streams	From compost sales, RDF supply, user charges, and carbon credits

6. Strengths of Indore Model

- **Integrated Urban Governance** combining enforcement, incentives, and engagement.
- Successful **convergence of SBM, AMRUT, Smart City Mission**, and local initiatives.
- Efficient **PPP models** in plant operation and waste processing.
- Use of **behavioral nudges** and social media to foster civic pride and compliance.

7. Key Challenges

- **Scalability** to other tier-2 cities with weaker governance or financial limitations.
- High cost of maintaining **digital monitoring systems** and ensuring transparency.

- Long-term **sustainability of revenue generation** from waste products.
- **Resistance from the informal sector** initially due to job formalization and reorganization.

8. Lessons for Circular Economy

- **Wet waste to energy (bio-CNG)** is a scalable CE solution for Indian cities.

Figure 5.1- BioCNG LOGO

Source - Indore Municipal Corporation

Figure 5.2 - Segregation of Waste

Source - Indore Municipal Corporation

Figure 5.3 - Segregation of Waste

Source - Indore Municipal Corporation

Figure 5.4 - The process outlined was followed by Indore Municipal Corporation

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

- **Behavioral change and citizen pride** are essential components, not just infrastructure.
- Cities must **empower ULBs** with skilled manpower, digital tools, and financial autonomy.
- **Multi-stakeholder collaboration** (citizens, government, private firms, NGOs) is the backbone of successful CE implementation.

9. Visual Additions (Optional for Thesis)

- Diagram: Flowchart of waste journey from household to resource recovery.
- Map: Ward-wise decentralized compost/MRF units.
- Graph: Waste diverted from landfill over 5 years.

10. Conclusion

Indore has successfully operationalized circular economy principles at scale. It demonstrates that with the right mix of policy, participation, and technology, Indian cities can transform their waste crisis into an opportunity for economic regeneration and environmental resilience

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Website: http://imcindore.mp.gov.in
Indore Smart City Progress Reports
NITI Aayog & UNEP (2021): Circular Economy in Municipal Solid Waste

Management
Case study of Indore included
Link: https://www.niti.gov.in/sites/default/files/2021-02/MSW_Report.pdf
TERI (The Energy and Resources Institute)
Case study evaluations of waste-to-energy and decentralized composting in Indore
https://www.teriin.org
****CSTEP India (2020):** Data Analytics for Municipal Solid Waste in India*
Comparative analysis featuring Indore
https://cstep.in
***GIZ India & ICLEI (2021):** Best Practices in Indian Cities for Solid Waste Management*
Includes Indore's MRFs and Bio-CNG initiative
https://www.giz.de/en/worldwide/317.html

5.2 Case Study 2 : Norway

Title: ***Towards a Circular Waste Economy – Norway's Integrated, Technology-Driven Waste Management Model***

1. Introduction

Norway, a leading nation in sustainable development, has integrated circular economy (CE) principles into its national waste strategy. With a strong legal framework, high public awareness, and advanced technologies, Norway's model demonstrates how high-income countries can close the loop on urban waste through innovation, producer responsibility, and systemic circular planning.

2. Background

Population: ~5.5 million

Urbanization Rate: ~83%

Municipal Solid Waste (MSW) Generated: ~2.3 million tons/year

Waste Generation per capita: ~430 kg/year (Eurostat 2023)

Landfilling Rate: <1% (among the lowest in the world)

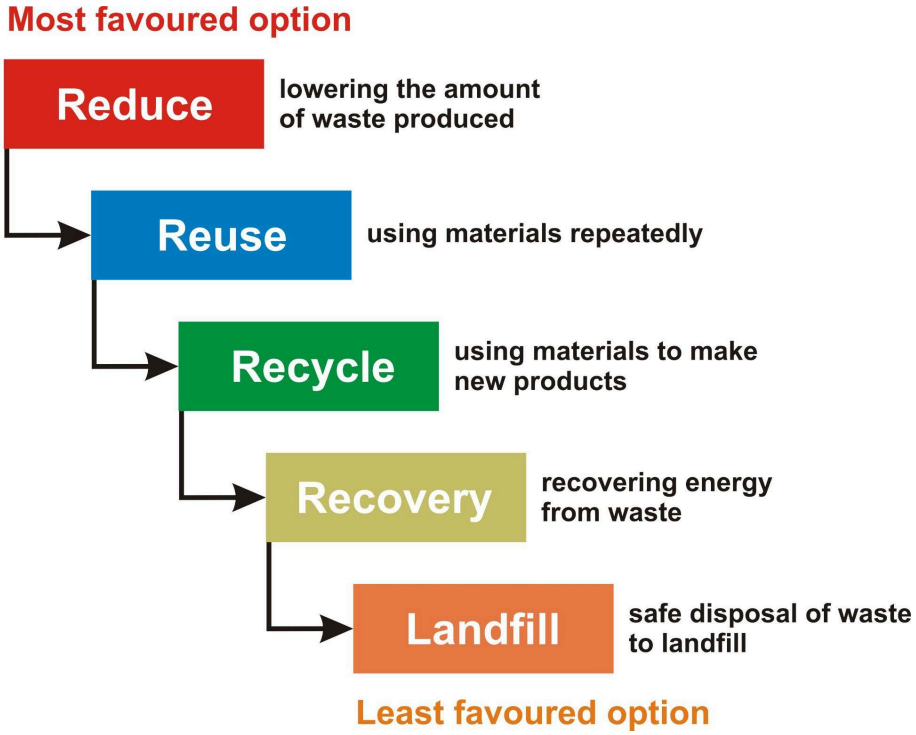
3. Key Interventions in Circular Waste Management

Circular Economy Approaches Implemented

Table 5.3 Key Interventions

Domain	Intervention
Waste Hierarchy Compliance	Strict enforcement of EU Waste Directive: prioritize prevention, reuse, recycling
Extended Producer Responsibility (EPR)	Strong EPR for packaging, electronics, batteries, cars, etc.
Source Segregation & Recycling	>95% households segregate waste into 3–7 categories
Energy Recovery	Widespread use of incineration with energy recovery; heat for district heating
Material Recovery Facilities (MRFs)	Automated MRFs sort mixed waste to recover metals, plastics, and paper
Organic Waste Processing	Anaerobic digestion of food waste into biogas and fertilizers

Figure 5.5 : Waste Hierarchy



Source : https://in.images.search.yahoo.com/search/images

4. Governance and Policy Framework

- **Responsible Body:** Norwegian Environment Agency (Miljødirektoratet)
- **Circular Economy Roadmap (2021):** Focuses on product lifecycle, material reuse, and reducing resource extraction
- **EU Membership Influence:** Follows **EU Green Deal** and **Circular Economy Action Plan**

Figure 5.6 : AI-Powered Robot

Source: hub-4.com

5. Community Engagement and Public Behavior

- Nationwide recycling campaigns via schools, media, and local municipalities
- **Deposit Refund System (DRS)** for bottles and cans (Infinitum system)
- Over 95% return rate — world-leading performance
- Digital tools/apps used to track waste and reward correct segregation

6. Outcomes & Impact

Table 5.4 Outcomes & Impact

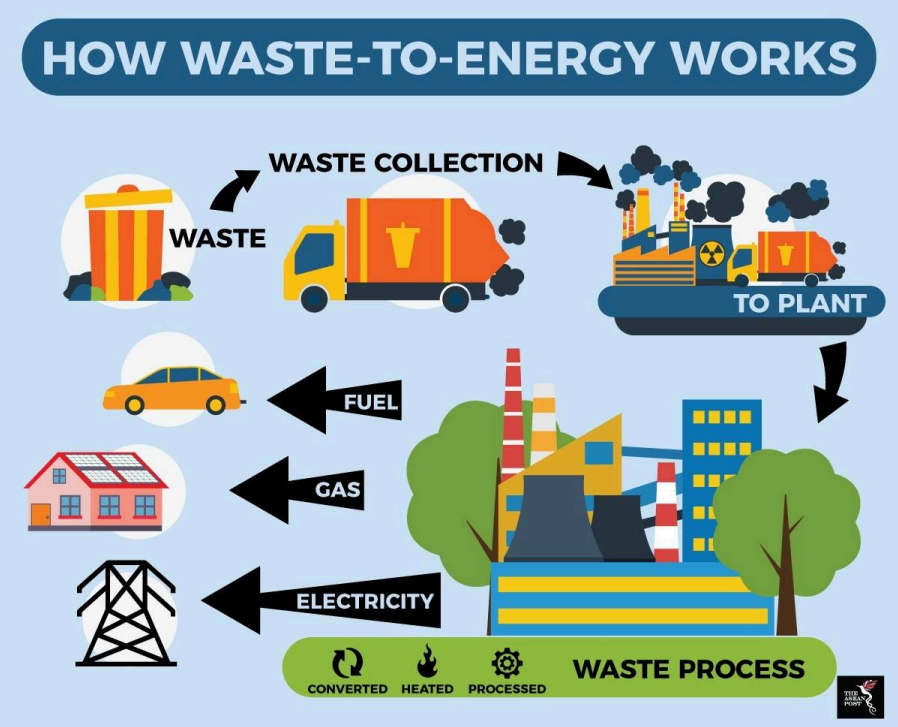
Indicator	Outcome
Recycling Rate	~45–50% (national average)
Landfilling	<1%
Energy from Waste	52% of residual waste used for district heating (waste-to-energy plants)
Biogas Production	Increasing from food and green waste
GHG Emission Reduction	Significant reductions via reduced landfilling and methane capture
Circular Product Development	Growth in reuse centers, upcycled products, and green procurement

Source: Norway Environmental Department

Figure 5.7 : Waste Vending Machines in Norway

Source: Norway Environmental Department

Figure 5.8 : Waste-to-Energy



Source: Norway Environmental Department

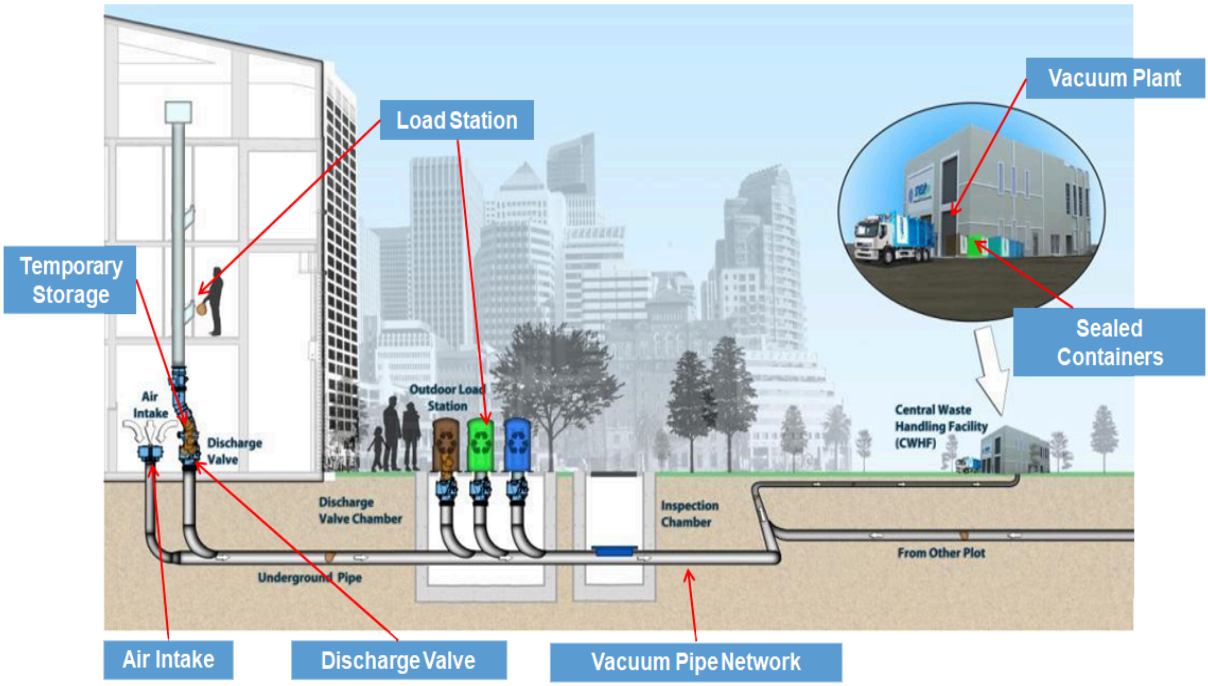
7. Strengths of the Norway Model

- Strong **legal enforcement** and producer responsibility policies
- Highly **digitized, automated infrastructure**
- **Public trust and participation** built over decades
- Clear focus on **waste prevention** and **resource efficiency**
- Leadership in **urban heating via energy recovery**

8. Key Challenges

- High dependency on **incineration** may conflict with higher CE goals (reuse > recovery)
- **Recycling contamination** issues persist despite segregation
- Need to increase **product repair, reuse, and remanufacturing** (still lagging behind EU targets)

Figure 5.9 : Waste collection by Underground Pipes in Norway



Source: Norway Environmental Department

9. Lessons for Developing Cities

- **Deposit systems** can drastically improve material recovery
- **Policy coherence** between local and national levels enhances implementation
- **Public-private partnerships** foster innovation and investment in CE infrastructure
- Investing in **public awareness and digital tracking tools** improves transparency and engagement

10. Conclusion

Norway offers a **highly evolved, structured model** for circular waste management, balancing prevention, recovery, and recycling. It demonstrates that strong **regulatory backing**, **citizen participation**, and **market-based instruments** like EPR and deposit schemes can lead to effective waste circularity. However, as it shifts beyond waste-to-energy toward true circularity, the next frontier is minimizing virgin resource use and promoting reuse/repair economies.

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Eurostat Waste Statistics: *https://ec.europa.eu/eurostat*

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EU Circular Economy Action Plan (2020):
https://ec.europa.eu/environment/circular-economy

Chapter 6 - Inference of the Literature & Case Study

6.1 Inference of the Literature Study

6.1.1 Inferences from the MoHUA Report (2021)

Paradigm Shift in Waste Management

- Transition from a **linear model** (collect → dispose) to a **circular economy** (reduce → reuse → recycle).
- Emphasis on **resource efficiency** and **waste as a resource** rather than a disposal issue.

Strategic Integration Imperatives

- Requires **synergy between**:
    - Public policy and governance.
    - Advanced technologies (e.g., digital tracking).
    - Active stakeholder participation (citizens, informal sector, private firms).

Structural Transformation Needs

- **Policy reorientation**.
- **Infrastructure modernization**.
- **Behavioral change** at the community level.

Alignment with National and Global Goals

- **Swachh Bharat Mission (SBM)**.
- **Atmanirbhar Bharat** (self-reliance through green jobs and innovation).
- **UN Sustainable Development Goals (SDGs)**, especially SDG 11 (Sustainable Cities) and SDG 12 (Responsible Consumption).

MoHUA Report Highlights

- **Decentralized waste processing** units.

    - **Capacity building** of Urban Local Bodies (ULBs).
    - **Incentives for green entrepreneurship**.
    - **Integration of informal sector** in formal systems.
- Stresses **Extended Producer Responsibility (EPR)** and **digital monitoring** of waste flows.

Identified Gaps

- **Weak financial frameworks** in ULBs hinder implementation.
- **Scalability issues** in smaller towns and peri-urban areas.
- Need for **customized, financially viable solutions** for cities like Lucknow.

6.1.2 Inferences from the Report Driving Sustainability Report (2021)

Paradigm Shift in Urban Waste Management

- Transition from **linear (collect → dispose)** to **circular systems (reduce → reuse → recycle)**.
- Emphasis on **resource recovery**, minimizing landfill dependence, and reducing environmental impact.

Need for Strategic Integration

- Effective waste management requires integration of:
    - **Public policy and governance frameworks**.
    - **Technology adoption** (e.g., digital waste tracking, data analytics).
    - **Active stakeholder participation**, including:
        - Citizens
        - Informal workers
        - Private sector players

Structural Reforms Required

- Reforms are not limited to logistics or operations—they require:
    - **Policy reorientation** toward sustainability.
    - **Infrastructure modernization** (e.g., MRFs, composting units).
    - **Behavioral transformation** through education and incentives.

Alignment with National & Global Goals

- Reinforces key missions:
    - **Swachh Bharat Mission (SBM)** – improved cleanliness, awareness, and waste segregation.
    - **Atmanirbhar Bharat** – creation of green jobs and decentralized entrepreneurship.
    - **UN SDGs**, especially:
        - **SDG 11**: Sustainable Cities and Communities.

        - **SDG 12**: Responsible Consumption and Production.

Policy Tools and Economic Interventions

- Recommended policy-level actions include:
    - **Tax incentives** for private recyclers and composting units.
    - **Subsidies** for waste-to-resource infrastructure.
    - **Regulatory mandates** for bulk waste generators and producers (via EPR).
- Emphasis on **aligning policies with carbon reduction and SDG targets**.

Use of Economic Instruments

- Proposes use of financial tools to reshape behavior:
    - **Performance-based incentives** for segregation and recovery at the ward level.
      Reward models that strengthen participation across formal and informal sectors.

Focus on Informal Sector Integration

- Recognizes that developing cities like Lucknow rely heavily on:
    - **Informal waste pickers**, scrap dealers, and aggregators.
    - Policies must focus on **formalizing their roles**, ensuring dignity, and improving livelihoods.

6.1.3 Inferences from the Report Zero-Waste Cities Comparative Study (2024)

Paradigm Shift in Waste Management

- Movement from a **linear approach** (collect → dispose) to a **circular economy** (reduce → reuse → recycle).
- Focus on **resource efficiency**, environmental sustainability, and systemic resilience.

Importance of Strategic Integration

- Effective models emphasize collaboration between:
    - **Public policy frameworks**
    - **Technology adoption** (monitoring, tracking, analytics)
    - **Stakeholder participation**, including citizens and private partners.

Case-Based Global Insights

- **Indore (India)**:
    - Success with **decentralized systems**, cleanliness awards, and ward-level initiatives.
    - Strong public awareness and civic pride.
- **Norway (Global)**:
    - Model of **data-driven waste governance**.
    - Extensive **public-private partnerships (PPP)**.
    - Universal source segregation and high recycling rates.

Structural Nature of Transition

- Transitioning to zero-waste cities involves:
    - **Policy reform** and compliance mechanisms.

- **Infrastructure investment** (e.g., Material Recovery Facilities, compost units).
- **Citizen behavior change** and ongoing public education.

Alignment with National and Global Goals

- **Swachh Bharat Mission** (cleanliness and sanitation).
- **Atmanirbhar Bharat** (localized employment, green jobs).
- **UN SDGs**—especially:
  - **SDG 11**: Sustainable Cities and Communities.
  - **SDG 12**: Responsible Consumption and Production.

Key Global Benchmarking Learnings

- Common practices across high-performing global cities:
  - **Decentralized models** of waste collection and treatment.
  - **Door-to-door education** on segregation and reduction.
  - **Regular monitoring and audits**.
  - **Innovative and adaptive policies**.

Role of Community Participation

- **Citizen-led initiatives**—including:
  - Micro-composting at household and community level.
  - Community-run **Material Recovery Facilities (MRFs)**.
- These approaches promote **ownership, reduce costs**, and improve sustainability.

6.1.4 Circular Economy Challenges in Indian Cities (2022)

Paradigm Shift to Circular Economy (CE)

- Moving away from a linear “collect–dispose” model to a sustainable model emphasizing **reduce, reuse, and recycle**.
- Treating **waste as a resource**, not just a nuisance.

Strategic Integration Imperative

- Successful CE models require:
    - Strong **public policy** alignment.
    - Adoption of **smart technologies** (monitoring, dashboards).
    - Inclusion of **stakeholders** (citizens, private players, informal sector).

Global & National Evidence

- **Indore (India)**: Proven success with decentralization, tech-based sanitation drives, and civic participation.
- **Norway (Global)**: Robust public-private partnerships and high-tech citizen-centric governance.

Key Governance Barriers in India

- **Institutional Weaknesses**:
    - Lack of coordination between municipal departments.
    - Fragmented roles and overlapping mandates.
- **Funding Gaps**:
    - Limited capital for infrastructure upgrades.
    - Inadequate revenue models for waste services.
- **Low Awareness & Capacity**:
    - Poor citizen engagement in smaller cities.
    - Limited capacity among municipal staff for data handling and monitoring.

Tier-2 City Challenges

- Many smaller urban areas struggle with:
    - Weak enforcement of SWM rules.
    - Data inaccuracy or absence of tracking mechanisms.
    - Lack of digital infrastructure for planning and performance evaluation.

Proposed Reforms for Better Governance

- **Circular Economy Cells** within ULBs:
    - Dedicated teams to design, coordinate, and monitor CE strategies.
- **Smart Governance Tools**:
    - Real-time dashboards to track segregation, collection, and processing.
    - Ward-wise performance analytics for transparency and accountability.

Alignment with Broader Goals

- Supports:
    - **Swachh Bharat Mission** – Clean cities through system-wide reform.
    - **Atmanirbhar Bharat** – Self-reliant systems for green employment.
    - **SDGs** – Especially SDG 11 (Sustainable Cities) & SDG 16 (Effective Institutions).

6.2 Inference of the Case Study

6.2.1 Case Study 1: Indore, Madhya Pradesh

Paradigm Shift to Circular Waste Economy

- Transition from **linear waste disposal (collect–dump)** to **circular systems** emphasizing:
    - **Reduce, Reuse, Recycle**
    - **Resource efficiency**
    - **Waste as an asset**

Indore: Model City for Cleanliness

- **Five-time winner** of “India’s Cleanest City” under Swachh Survekshan.
- Demonstrates a **complete integration of policy, technology, and people’s participation**.

Core Best Practices from Indore

- **100% Source Segregation**: Mandatory and enforced at household level.
- **Efficient Collection**: Door-to-door, timely, and monitored via RFID tags.
- **Decentralized Composting**: Ward-level units reduce load on central landfills.
- **Biogas Generation**: Organic waste used to power city buses and streetlights.
- **Material Recovery Facility (MRF)**: Well-managed sorting and recycling operations.
- **Real-time Monitoring**: GPS-enabled trucks, RFID-tagged bins, smart dashboards.

Governance & Community Involvement

- **PPP Model**: Robust private sector participation in logistics and operations.
- **IEC Campaigns**: Continuous awareness and behavioral nudges through:

    - Community meetings
    - Street plays, branding, school programs.
- **Citizen Engagement**: Feedback loops, complaint redressal apps, and incentives for compliance.

Relevance for Lucknow (Alambagh & Zone 8)

- Densely populated urban wards face similar:
    - **Waste generation intensities**
    - **Infrastructural constraints**
- Indore's decentralized and **technology-driven model** can be customized and piloted in Lucknow for:
    - **Ward-wise segregation goals**
    - **Micro-composting units**
    - **Waste picker formalization**

Alignment with Policy Goals

- **Swachh Bharat Mission (SBM)**: Indore exemplifies mission objectives.
- **Atmanirbhar Bharat**: Promotes green jobs through decentralized waste processing.
- **UN SDGs**:
    - **Goal 11**: Sustainable cities.
    - **Goal 12**: Responsible consumption and production.

6.2.2 Case Study-2 : Norway

1. Paradigm Shift to Circular Economy

- Shift from **linear model** (collect → dump) to **circular model** (reduce → reuse → recycle).
- Waste is treated as a **resource**, not just a disposal problem.
- Emphasis on **sustainability and efficiency** in urban systems.

Strategic Integration for Zero-Waste Systems

- Requires coordination between:
    - **Public policy reforms**
    - **Technology adoption** (e.g., AI, blockchain)
    - **Stakeholder engagement** (citizens, private sector, informal workers)

Lessons from Global Best Practice: Norway

- **Advanced Technology Adoption**:
    - **Automated sorting plants**
    - **Pneumatic waste collection systems**
    - **AI for waste quality monitoring**
    - **Blockchain for e-waste tracking**
- **Strong Producer Responsibility**: Enforced accountability for product lifecycle.
- **Public Awareness**: Incentives and education ensure citizen participation.
- **Zero landfill strategy**: High recycling and energy recovery.

Application in Lucknow (Alambagh & Zone 8)

- High-density areas can benefit from:

    - **Decentralized compost units**
    - **Smart bin monitoring**
    - **RFID-tagged collection vehicles**
    - **Mobile apps for public feedback**
- Tailor strategies to local **waste composition** and **infrastructure gaps**

Alignment with Broader Missions

- **Swachh Bharat Mission (SBM)**: Promotes clean, sustainable urban systems.
- **Atmanirbhar Bharat**: Encourages local innovation in waste solutions.
- **UN SDGs**:
    - **SDG 11** – Sustainable Cities and Communities
    - **SDG 12** – Responsible Consumption and Production
    - **SDG 13** – Climate Action through carbon footprint reduction

Chapter 7 - Study Area Overview

7.1 Introduction of Lucknow City

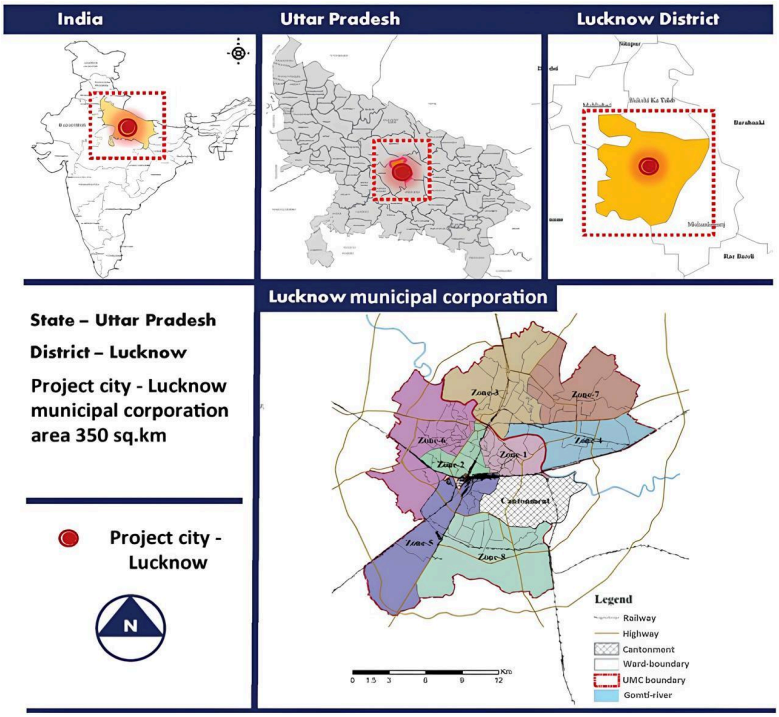
7.1.1 Historical Context

Lucknow, the capital of Uttar Pradesh, boasts a rich history influenced by Mughal and Awadhi cultures. During the Mughal era, it was a prominent center for arts and culture. In the 18th century, under the rule of the Nawabs of Awadh, the city flourished as a hub for literature, music, and cuisine. The 1857 uprising, known as the First War of Indian Independence, saw Lucknow as a significant battleground. Post-independence, the city has evolved into a modern metropolis while retaining its historical charm.

7.1.2 Geographical Features & Location

- **Coordinates**: 26°30′N latitude and 81°13′E longitude.
- **Elevation**: 123 meters above sea level.
- **Climate**: Dry sub-humid to semi-arid, with average annual rainfall around 979 mm.
- **Rivers**: The Gomti River divides the city into Trans-Gomti and Cis-Gomti regions.
- **Soil**: Alluvium calcareous sandy loam, typical of the upper Gangetic plain.

Figure 7.1 : Connectivity Maps



7.1.3 Demographic Profile

- **Population (2011 Census)**: 2,817,105.
- **Current Population (as per LNN, 2019)**: 3,391,208.
- **Gender Distribution**: 1,765,632 males and 1,625,576 females.
- **Households**: 557,130, with an average household size of 6.09.
- **Literacy Rate**: 84.72%, surpassing the state average of 67.68%.
- **Languages Spoken**: Hindi (88.16%) and Urdu (10.26%).
- **Sex Ratio**: 915 females per 1,000 males.

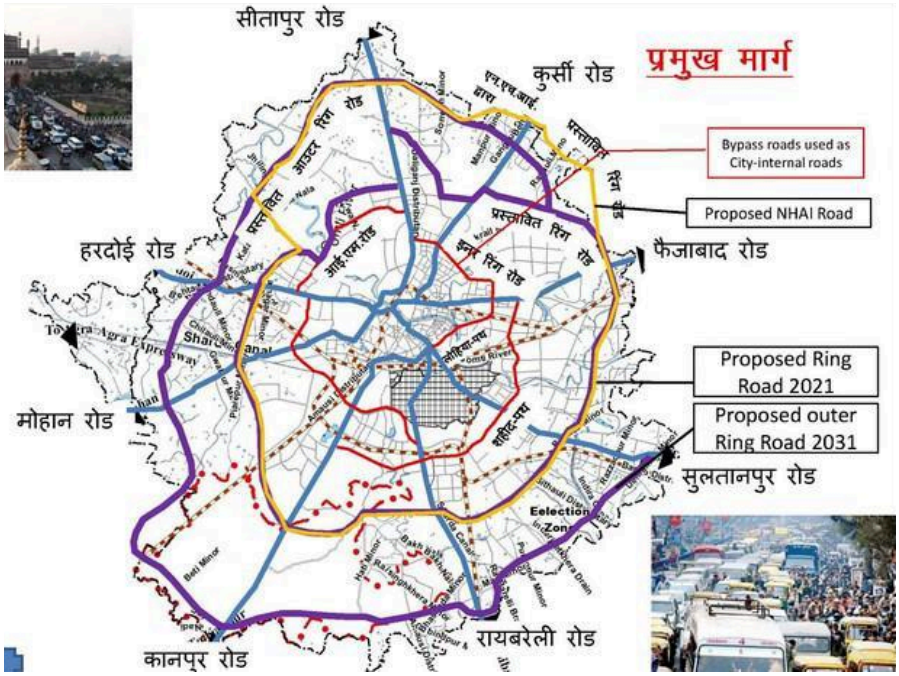
7.1.4 Administrative Details

- **Area**: 631 km², making it one of the largest cities in India by area.
- **Administrative Zones**: 8 zones and 110 wards.
- **Urban Local Body**: Lucknow Municipal Corporation (LMC).
- **Urban Development Initiatives**: Part of the Atal Mission for Rejuvenation and

Urban Transformation (AMRUT) and the Smart City Mission.

7.1.5 Connectivity

Figure 7.2 : Road Map



Road Connectivity

- **National Highways:** NH-27, NH-30
- Lucknow–Agra Expressway
- Purvanchal Expressway (via Lucknow)
- **Ring Road:** Lucknow Outer Ring Road (under development)
- **Bus Terminals:**
    - Alambagh Bus Terminal
    - Kaiserbagh Bus Terminal
    - Charbagh Interstate Bus Stand
- **Major Roads:**
    - Faizabad Road
    - Sitapur Road

- Kanpur Road
- Rae Bareli Road
- Sultanpur Road

Rail Connectivity

- **Major Railway Stations:**
  - Charbagh (Lucknow NR) – main junction
  - Lucknow Junction (LJN) – NER division
  - Gomti Nagar Railway Station
  - Badshahnagar Railway Station
  - Aishbagh Railway Station
- **Connected Cities:**
  Delhi, Mumbai, Kolkata, Chennai, Varanasi, Gorakhpur, Kanpur, Patna, Chandigarh

Air Connectivity

- **Chaudhary Charan Singh International Airport (Amausi):**

Metro Connectivity

- **Lucknow Metro (North–South Corridor):**
  - Charbagh to Munshipulia (Operational)
- **Key Stations:** Hazratganj, Charbagh, Alambagh, Krishna Nagar, Polytechnic

7.1.6 Waste Segregation & Recycling

- **Segregation at Source**: Initiatives to segregate biodegradable and non-biodegradable waste at the household level.
- **Recycling Efforts**: Non-biodegradable waste is being recycled for various commercial uses, including construction of roads, tiles, and electricity generation.

7.1.7 Environmental Initiatives

- Legacy Waste Management: The Shivri plant has processed 9.5 lakh metric tons of

legacy waste, reclaiming 20 acres of land. The goal is to process all remaining legacy waste by December 2025.

- Green Lucknow Initiative: Planting of five lakh saplings to enhance urban greenery and improve air quality.

Solid Waste Management in Lucknow

Daily Waste Generation: Approximately 2,000 to 2,200 metric tons.

- Biodegradable: 40% (800–880 MT)
- Non-biodegradable: 60% (1,200–1,320 MT)

Processing Facilities:

- **Shivri Plant**: The third unit, with a capacity of 700 MT, became operational in March 2025, enabling the processing of all daily waste.
- **Fixed Compactor Transfer Station (FCTS)**: Inaugurated in Bhaisora to replace open dumpers with sealed compactors, enhancing sanitation and environmental safety.

Figure 7.3 : Bhaisora Fixed Compactor Transfer Station

Source : Nagar Nigam Lucknow

7.2 Introduction of Study Area

This section presents an overview of Solid Waste Management (SWM) practices in Zones 5 (Alambagh) and 8 (Aashiana, Telibagh, Vrindavan Yojna) of Lucknow, drawing from verified municipal records and academic literature. It incorporates flow charts illustrating the complete waste journey—from collection to final disposal—and provides references to support further research and analysis.

7.2.1 Administrative Overview

- **Zone 5** and **Zone 8** are part of the **Lucknow Municipal Corporation (LMC)**, which governs the city and is divided into 8 administrative zones and 110 wards .

- **Zone 8** includes 13 wards: Sharda Nagar I & II, Ibrahimpur I & II, Raja Bijli Pasi I & II, Kharika I & II, Hindnagar, Vidyawati I–III, and Atal Bihari Vajpayee Ward .

List of Wards

Zone 5 encompasses 11 wards, including:

- Sarojini Nagar Ward Part 1
- Babu Kunj Bihari
- Chitragupt Nagar
- Gurunanak Nagar
- Om Nagar
- Geeta Palli Ward
- Sarojini Nagar Part 2
- Keshri Kheda Ward
- Ramji Lal Nagar
- Sardar Patel Nagar
- Guru Govind Singh

Zone 8 encompasses 13 wards, including:

- Sharda Nagar I & II
- Ibrahimpur I & II
- Raja Bijli Pasi I & II
- Kharika I & II
- Hindnagar
- Vidyawati I, II & III
- Atal Bihari Vajpayee Ward

7.2.2 Demographic Overview

Zone 5

- **Population**: Approximately 1.2 to 1.5 lakh residents.
- **Key Localities**: Includes areas like RDSO Colony, Puran Nagar, Ram Nagar, Geeta Palli, Sardari khera, Krishna Nagar,Baldi Khera & Manas Nagar .
- **Socio-Economic Profile**: Predominantly middle-income residential neighborhoods with a mix of professionals, traders, and students.
- **Infrastructure**: Well-developed road networks, educational institutions, and healthcare facilities.

Zone 8

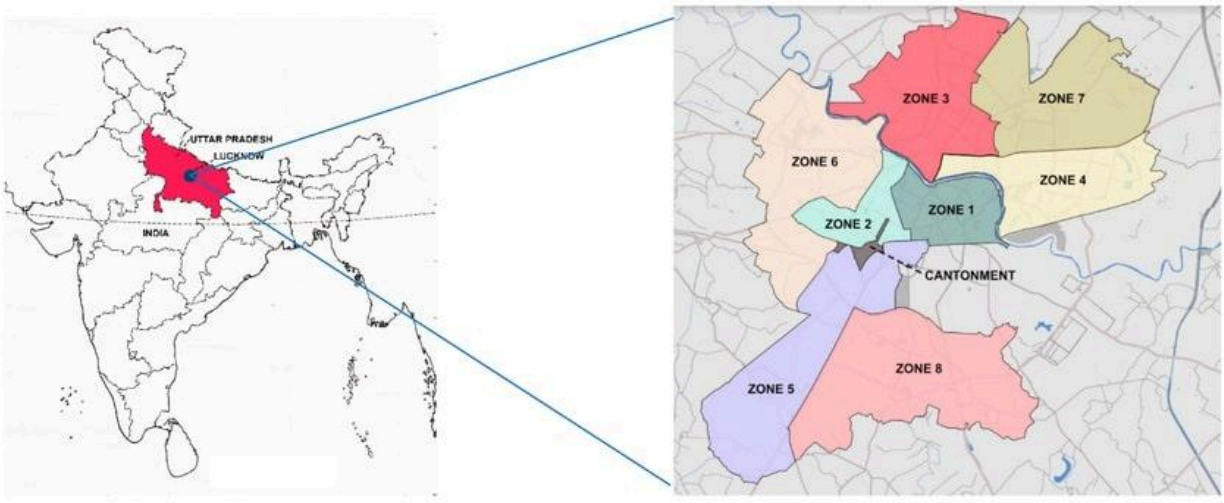
- **Population**: Approximately 1.5 to 1.8 lakh residents.

Key Localities: Comprises over seven dozen localities including Eldeco Udyan I & II, Sainik Nagar, Vrindavan Yojna, Kharika Telibagh, LDA Colony Rae Bareli Road, and Ashiana.

- **Infrastructure**: Presence of parks, educational institutions, and markets.

Socio-Economic Profile: A mix of residential, commercial, and institutional areas.

Figure 7.4 : Zone Map



Flow of Municipal Solid Waste

The flow of municipal solid waste in Lucknow:

- Waste Generation at Household/Commercial Level
- Door-to-Door Collection (Two-bin system: dry and wet waste)
- Transportation to Local Collection Points
- Transfer to Transfer Stations (e.g., Bhaisora FCTS)
- Transportation to Shivari Processing Plant, Mohan Road
- Processing (Segregation, Composting, RDF Recovery, etc.)
- Disposal of Rejects to Engineered Landfill or Incineration

Key Features in Zones 5 & 8

- Shivari Plant, Mohan Road – Primary solid waste processing facility.
- Fixed Compactor Transfer Station (FCTS), Bhaisora – Ensures sealed transport of waste

Solid Waste Management Initiatives

1. Deployment of Electric Garbage Collection Vehicles

150 electric garbage collection vehicles were introduced across Zones 2, 5, and 8 to enhance door-to-door collection. This initiative is expected to create employment for around 5,000 individuals, including women, directly and indirectly.

2. Fixed Compactor Transfer Stations (FCTS)

A Fixed Compactor Transfer Station was inaugurated in Bhaisora to replace open dumpers with sealed capsule-type compactors. These compactors can handle 29 metric tonnes of waste per trip, ensuring cleaner, safer waste transfer with minimal odor and spillage.

3. Community Engagement and Awareness Campaigns

Zone 8 has participated in:
- 'Ek Ped Maa Ke Naam': A tree plantation drive.
- 'Plogging for Plastic': Jogging while collecting plastic litter.
- 'Human Chain for Environment': Citizens forming human chains to raise environmental awareness.

4. Plastic Waste Management Initiatives

RCUES Lucknow organized a seminar for Urban Local Bodies on effective strategies to manage and reduce plastic waste on World Environment Day.

4 Decade Overview of Solid Waste Management in the Study Area

1. **Explosive Growth, Rising Waste:**
    - Population jumped from ~55 k (1980) to ~340 k (2024); daily waste ≈ 650 TPD.
    - Plastic fraction doubled, underscoring the urgency for 3R solutions.
2. **Contrasting Urban Morphology (Perfect A/B Lab):**
    - Alambagh – organic, high-density transport-commercial hub with heavy floating population.
    - Ashiyana – grid-planned, RWA-driven, higher income/literacy.

    ➜ Provides two distinct but complementary contexts to prove scalability.
3. **Robust First-Mile Logistics Already in Place:**

- 60+ GPS-equipped “Chhota Haathi” mini-tippers servicing Zones 5 & 8.
- Metro, six-lane Kanpur Road & Amar Shaheed Path allow rapid haulage.

4. **Sealed Transfer Infrastructure:**
   - Kesari Khera (Zone 5) & Bhaisora (Zone 8) FCTS/PCTS handle compacted waste, minimising spillage and odour.
5. **Backbone Processing:**
   - Shivri mega-plant upgraded to 2 000 TPD with composting, RDF and legacy-waste biomining—ready to absorb residual streams.
6. **Community & Institutional Capital:**
   - 40+ active RWAs, trader associations, Eco-clubs; SBM drives entrenched segregation literacy (> 65 % households practise some form).
   - Informal waste workers can organize into cooperatives, enabling smoother integration into formal systems through collective bargaining, training, and recognition.
7. **Tech & Pilot Assets:**
   - IoT-enabled fill-sensor bins monitor waste levels in real-time, ensuring timely collection and reducing overflow at terminals and markets.
   - CSR-funded ward composters and a 5 TPD bio-CNG pilot in Vrindavan Yojna.
8. **Economic Readiness:**
   - Average HH income ₹34–45 k/month; surveys show 60 % willing to pay user fees if service quality is visible.
   - Strong retail/e-commerce nodes generate recyclables that guarantee MRF revenue.
9. **Policy Alignment:**
   - Fits SBM-U 2.0 “Garbage-Free” star ratings, UP Circular Economy Roadmap, Smart City KPI dashboards & SDGs 11/12.

10. Projected Impact (3-Year Horizon):

- 80 % landfill diversion via source segregation + neighbourhood compost/MRF spokes.
- 20 % cut in collection mileage through GPS-IoT routing.
- 1 500+ green jobs (including formalised waste pickers).

Chapter 8 - Integration of Kano Model

8.1 List Of Features

Table 8.1 Features

Code	Description	
F1	Door-to-door daily waste collection	P
F2	Waste segregation at source	A
F3	Incentives for proper household waste segregation	P
F4	Digital mobile app for complaints & pickup tracking	I
F5	Community recycling & composting centers	M
F6	Frequency of waste pickup	I
F7	Dedicated bins for hazardous waste	A
F8	Cleanliness and hygiene at waste collection points	A
F9	Automated GPS tracking of waste collection vehicles	I
F10	Regular public awareness and training sessions	R
F11	Clear, multilingual informative signage	I
F12	Decorative/aesthetic design of public bins	M
F13	Stringent penalties for improper disposal	A
F14	Reward system for model cleanliness wards	A
F15	Monthly community cleanliness drives	I
F16	Regular reporting on waste management status	P
F17	Provision of protective gear to sanitation workers	P
F18	Night-time waste collection to reduce daytime congestion	A
F19	Efficient complaint resolution turnaround	I
F20	Support and integration of informal waste collectors	P
F21	Availability of recycling bags/bins for households	M
F22	Waste-to-energy or advanced recycling facilities	P
F23	Regular waste characterization audits	I
F24	Biodegradable waste composting at household/community level	A
F25	Rain shelter over public waste bins	A
F26	Customer service hotline specifically for SWM queries	P

8.2 List Of Stakeholders

User Id	User Name	Segment
A	User 1	Urban Local Bodies (ULBs) – Implementation & monitoring
B	User 2	Citizens/Residents – Waste segregation & behavior change
C	User 3	Informal Waste Workers – Primary recycling workforce
D	User 4	Private Sector/Investors – Infra development, PPP
E	User 5	Technology Providers – AI, IoT, data platforms
F	User 6	Municipal Staff – Ground-level operations
G	User 7	Resident Welfare Associations (RWAs) – Local engagement
H	User 8	NGOs – Awareness & training support
I	User 9	Academic Institutions – Research & curriculum development
J	User 10	State Urban Development Department (SUDD) – Policy lead agency
K	User 11	Smart City Mission Cell – Strategic coordination
L	User 12	Waste Management Authorities (WMAs) – Technical & infra management
M	User 13	State Pollution Control Board (SPCB) – Environmental compliance
N	User 14	CSR Contributors (Corporates) – Funding via CSR mandates
O	User 15	Policy Review Committees – Oversight and revision of strategies

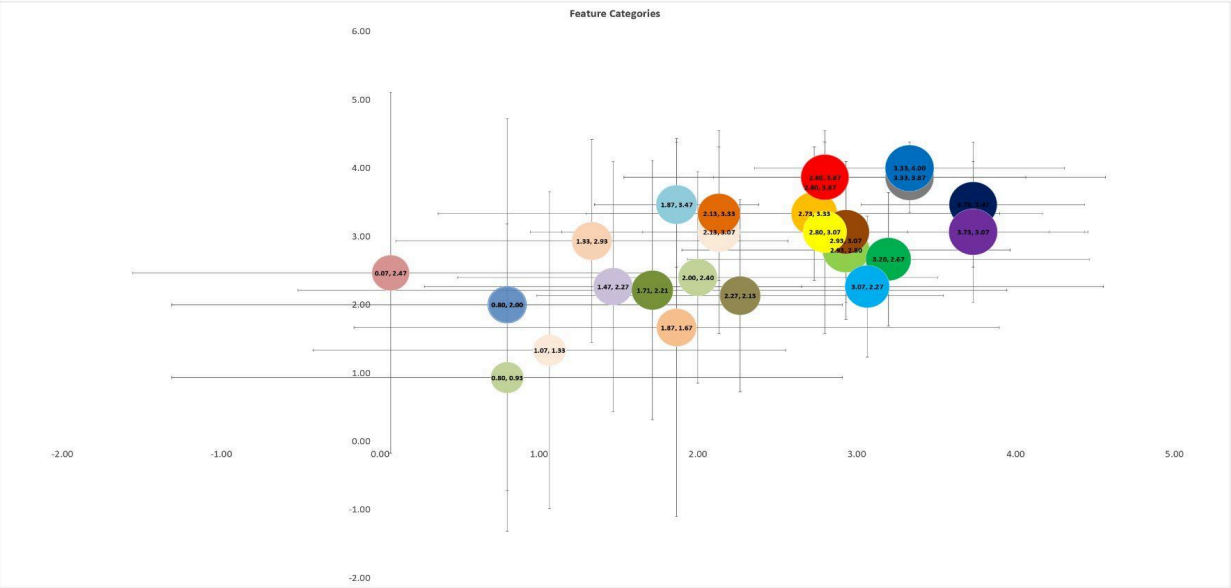
8.3 Kano Analysis Table-

Table 8.1 Kano Regression Table

	Continuous Analysis							Discrete Analysis							
Feature	Dysfunctional (X)	Functional (Y)	Importance (Z)	Category	Std Dev X	Std Dev Y	Std Dev Z	M	P	A	I	R	Q	Total	Category
F1	3.33	3.87	8.27	P	1.23	0.52	1.24	6.67%	66.67%	26.67%	0.00%	0.00%	0.00%	100.00%	P
F2	2.80	3.87	8.20	P	1.26	0.52	0.83	6.67%	40.00%	53.33%	0.00%	0.00%	0.00%	100.00%	A
F3	3.73	3.47	8.07	P	0.70	0.92	1.24	26.67%	60.00%	13.33%	0.00%	0.00%	0.00%	100.00%	P
F4	1.47	2.27	5.47	A	1.19	1.83	1.86	0.00%	6.67%	40.00%	53.33%	0.00%	0.00%	100.00%	I
F5	3.73	3.07	8.33	P	0.70	1.03	1.01	46.67%	40.00%	13.33%	0.00%	0.00%	0.00%	100.00%	M
F6	2.93	2.80	7.80	P	1.03	1.01	1.38	26.67%	20.00%	20.00%	33.33%	0.00%	0.00%	100.00%	I
F7	2.13	3.07	6.27	P	1.19	1.49	2.21	0.00%	20.00%	46.67%	33.33%	0.00%	0.00%	100.00%	A
F8	1.87	3.47	5.93	A	0.52	0.92	1.84	0.00%	0.00%	73.33%	26.67%	0.00%	0.00%	100.00%	A
F9	2.27	2.13	5.87	P	1.28	1.41	1.86	26.67%	0.00%	20.00%	46.67%	6.67%	0.00%	100.00%	I
F10	1.87	1.67	5.60	I	2.03	2.77	2.82	6.67%	26.67%	26.67%	13.33%	26.67%	0.00%	100.00%	R
F11	2.00	2.40	5.40	A	1.51	1.55	2.82	0.00%	26.67%	13.33%	60.00%	0.00%	0.00%	100.00%	I
F12	3.20	2.67	7.20	P	1.26	0.98	1.38	40.00%	26.67%	6.67%	26.67%	0.00%	0.00%	100.00%	M
F13	2.73	3.33	7.47	P	1.44	0.98	1.59	13.33%	33.33%	33.33%	20.00%	0.00%	0.00%	100.00%	A
F14	0.07	2.47	4.93	A	1.62	2.64	2.02	0.00%	6.67%	66.67%	6.67%	20.00%	0.00%	100.00%	A
F15	1.07	1.33	3.80	I	1.49	2.32	2.43	0.00%	0.00%	33.33%	46.67%	20.00%	0.00%	100.00%	I
F16	2.13	3.33	6.33	P	1.77	0.98	1.99	0.00%	40.00%	26.67%	33.33%	0.00%	0.00%	100.00%	P
F17	2.93	3.07	7.60	P	1.28	1.03	1.70	20.00%	33.33%	20.00%	26.67%	0.00%	0.00%	100.00%	P
F18	1.33	2.93	5.67	A	1.23	1.49	1.74	6.67%	0.00%	60.00%	33.33%	0.00%	0.00%	100.00%	A
F19	0.80	0.93	3.80	I	2.11	2.25	2.40	20.00%	0.00%	26.67%	33.33%	20.00%	0.00%	100.00%	I
F20	2.80	3.87	8.00	P	1.26	0.52	1.51	0.00%	46.67%	46.67%	6.67%	0.00%	0.00%	100.00%	P
F21	3.07	2.27	7.00	P	1.49	1.03	1.59	60.00%	6.67%	13.33%	20.00%	0.00%	0.00%	100.00%	M
F22	3.33	4.00	8.33	P	0.98	0.00	0.79	0.00%	66.67%	33.33%	0.00%	0.00%	0.00%	100.00%	P
F23	1.71	2.21	6.07	A	2.23	1.90	2.76	0.00%	26.67%	13.33%	33.33%	20.00%	6.67%	100.00%	I
F24	0.80	2.00	5.47	I	2.11	2.73	2.65	0.00%	13.33%	46.67%	13.33%	26.67%	0.00%	100.00%	A
F25	0.80	2.00	4.87	I	2.11	2.73	2.60	0.00%	13.33%	46.67%	13.33%	26.67%	0.00%	100.00%	A
F26	2.80	3.07	6.73	P	1.66	1.49	2.38	20.00%	40.00%	26.67%	13.33%	0.00%	0.00%	100.00%	P

8.4 Kano Graphs

Figure 8.1 Kano Graph



8.5 Inferences Of The Kano Analysis

The Kano model classifies 26 proposed product/service features (F1–F26) into categories reflecting their impact on user satisfaction: Attractive (A), Performance (P), Must-be (M), Indifferent (I), Reverse (R), and Questionable (Q).

Attractive (A):
Delight users when present but not expected. Boost satisfaction significantly.
E.g., innovative or tech-driven features.

Performance (P):
Directly linked to satisfaction—more is better.
E.g., efficient waste collection or service responsiveness.
Must-be (M):
Basic expectations. Absence causes strong dissatisfaction.
E.g., door-to-door waste service.

Indifferent (I):
Presence or absence doesn't affect users much.
E.g., non-functional design details.

Reverse (R):
Users prefer not to have them—can reduce satisfaction.
E.g., overly complex instructions.

Questionable (Q):
Confusing responses—may indicate unclear questions or misunderstood features.

E.g., vague digital tools or survey errors.

Total features assessed: 26
Attractive (A): 8 features
Performance (P): 7 features
Indifferent (I): 7 features
Must-be (M): 3 features
Reverse (R): 1 features

Importance Scores by Category

Attractive (A): Avg. importance 6.1
Indifferent (I): Avg. importance 5.46
Must-be (M): Avg. importance 7.51
Performance (P): Avg. importance 7.62
Reverse (R): Avg. importance 5.6
Top 5 Features by Importance

- F5:(Community recycling & composting centers) with a Importance=8.33 → Must-be feature
- F22:(Waste-to-energy or advanced recycling facilities) Importance=8.33 → Performance feature
- F1:(Door-to-door daily waste collection) Importance=8.27 → Performance feature
- F2:(Waste segregation at source) Importance=8.2 → Attractive feature
- F3:(Incentives for proper household waste segregation) Importance=8.07 → Performance feature

Key Inferences by Kano Category

Performance (P) Features – Key Insights

Total Features Identified:
7 features have been categorized under this class.

Top-Scoring Performance Features:
F22, **F1**, and **F3** are the most critical, each with an **importance score exceeding 8** (on a 10-point scale), indicating:

- These are **high-priority areas**.
- Users **expect them to perform well** and derive tangible value from their success.

Implication for Policy or Service Design:

- These features should be **continuously improved** and **measured quantitatively**.

- Success can be tracked using **metrics like frequency, accuracy, efficiency**, and **coverage**.

Examples of Actions:

- For F1 (e.g., real-time waste tracking):
  → Ensure GPS tracking, timely dashboard updates, and response transparency.

- For F3 (e.g., grievance redressal systems):
  → Ensure fast turnaround, feedback loops, and user satisfaction audits.

- For F22 (e.g., timely collection):
  → Ensure strict schedules, route optimization, and monitoring.

Strategic Priority:

- These features should be treated as **core differentiators** in system performance.

- Consider them **"value creators"** for both users and service providers.

Must-be (M) Features – Key Insights

Total Features Identified:
3 features fall into this category, including **F5**.

Importance Score:

- These features carry a **high mean importance score of 7.51**, indicating that users **expect them by default**.

- Their absence can **break trust** and result in **negative perceptions**, even if other features are performing well.

Implication for Service/Program Design:

- These are **non-negotiable elements** and must be ensured **before** rolling out any advanced or value-added features.

Examples of Likely Must-be Features:

- **F5** (e.g., availability of basic waste bins or regular primary collection):
  → A **basic infrastructure provision** without which the entire system appears dysfunctional.

- Others might include **worker safety equipment**, **legal compliance**, or

accessibility of service to all residents.

Design and Communication Strategy:

- These features need **silent assurance** — users should feel these are **always available** without needing to ask.
- They form the **foundation layer** of user experience and operational credibility.

Strategic Priority:

- Treat these as **"hygiene factors"**.
- Address them **first in resource allocation**, infrastructure development, and training modules.

Attractive (A) Features – Key Insights

Total Identified:
8 features, including F2 and F6, are classified as Attractive.

Importance Score:
Average score of **6.1**, indicating moderate-to-high potential to enhance user satisfaction.

Strategic Value:

- Act as **differentiators** and create a **"wow" factor**.
- Strengthen **public approval and user experience**.

Examples:

- **F2**: Real-time waste tracking app.
- **F6**: Incentives for participation.
- Others: AI-based bins, gamified tools, compost giveaways.

Implementation Strategy:

- Add **after Must-be and Performance features** are secured.
- Pilot in focus areas like **Alambagh or Zone 8**.

Design & Communication:

- Use for branding and innovation.

- Promote via **IEC campaigns.**

Monitoring & Feedback:

- Collect **user feedback** and monitor adoption using digital tools.

Policy Alignment:
Supports **Atmanirbhar Bharat**, **Swachh Bharat**, and **SDGs 11 & 12**.

Indifferent (I) Features – Key Points

Total Identified:

- **7 features** fall under the *Indifferent* category.

Importance Score:

- Average importance score is approximately **5.46**, indicating **low emotional impact** on users.

User Perception:

- These features **neither satisfy nor dissatisfy** users.
- Their **presence or absence** does not significantly influence user experience.

Strategic Priority:

- Can be **deprioritized** in early-stage planning or tight budgets.
- Focus should remain on **Must-be**, **Performance**, and **Attractive** features first.

Resource Allocation:

- **Limited return on investment** if resources are spent on improving these.
- Allocate funds to these only if operational efficiencies or backend benefits justify them.

Potential Use Case:

- May still support **secondary functions** or **internal process optimization**.
- Reassess periodically as user expectations evolve.

Design Implication:

- Avoid overdesigning or marketing these features as value drivers.

- Monitor in case they **shift categories** due to changing trends or awareness.

Reverse (R) Feature – Key Points

Total Identified:

- Only **one feature** is classified as **Reverse** (e.g. needs specification).

User Reaction:

- **Enhancement of this feature decreases user satisfaction**.
- Indicates a **misalignment with user expectations or preferences**.

Implications:

- The feature may be seen as **unnecessary, intrusive, or counterproductive**.
- Could reflect **forced behavior change, over-automation, or privacy concerns**.

Design Response:

- Requires **reassessment or redesign**.
- Consider **modifying, simplifying, or completely removing** the feature.

Strategic Risk:

- Continuing to develop or promote this feature could **harm user trust**.
- Might generate **complaints or pushback**, undermining broader adoption.

Examples (Hypothetical):

- Forced app notifications, **mandatory registration for basic services**, or overly complex gamification elements.

Action Priority:

- Treat as a **high-priority corrective**.
- Flag for **internal review and user experience evaluation**.

Chapter 9 - Proposals

9.1 Policy Driven Proposals

Integrated Incentive-Based Policy Framework for Circular Economy in Urban Solid Waste Management

Policy Vision:

To enable a transition from a linear to a circular solid waste management system by incentivizing stakeholder participation, infrastructure development, innovation, and behavioral change at multiple levels.

1. Citizen and Source-Level Incentives

Objective: Promote waste minimization, segregation at source, and community participation.

- **Property Tax Rebates:** Households and institutions that consistently demonstrate proper waste segregation and onsite composting practices are eligible for annual property tax rebates, encouraging sustainable behavior and reducing the burden on municipal waste systems.
- **Digital Reward System:** A user-friendly mobile app monitors household contributions of recyclable and compostable waste, assigning reward points that can be redeemed as digital vouchers, thus promoting active citizen participation in circular waste practices.
- **Recognition Awards:** Certification and public acknowledgment of “Zero Waste Societies,” schools, and market complexes that meet CE benchmarks.

2. Informal Sector Integration and Empowerment

Objective: Integrate informal waste workers into the formal system with dignity, security, and productivity.

- **Certified Skill Training:** Government-funded training programs for informal workers on recycling, sorting, and composting, with stipends upon course completion.
- **Social Security Coverage:** Informal waste workers receive free enrollment in government welfare schemes that provide health insurance, accident protection, and pension benefits, ensuring social security and dignity within the circular waste management system.
- **Guaranteed Material Purchase Price:** Buy-back centers managed by

municipalities or cooperatives offer guaranteed minimum support prices for recyclable dry waste, securing fair income for waste collectors and promoting consistent material recovery in circular systems.

3. Decentralized Infrastructure Incentives

Objective: Facilitate setup and operations of CE infrastructure like composting units, MRFs, and biogas plants.

- **Capital Investment Subsidies:** 40–50% subsidy for infrastructure establishment, prioritizing community-level and decentralized systems.
- **Concessional Land Use:** Municipalities allocate government land at subsidized lease rates to encourage the establishment of circular economy infrastructure like composting units, MRFs, and biogas plants, reducing capital barriers for sustainable projects.
- **Operational Grants:** Municipal or state governments provide grants to cover the first three years of operations and maintenance (O&M) for circular waste facilities, ensuring financial stability during initial implementation and scaling phases.

4. Private Sector and Public-Private Partnership (PPP) Incentives

Objective: Encourage private investment and expertise in circular waste processing systems.

- **Tax Incentives:** Investors in recycling and waste-to-energy facilities receive GST exemptions and accelerated depreciation benefits, reducing financial burdens and incentivizing private sector participation in building circular economy-based waste management systems.
- **Viability Gap Funding (VGF):** Private partners receive performance-based financial disbursals tied to measurable outcomes such as material recovery rates, local job creation, and carbon emissions reduction, promoting accountability and efficiency in circular waste initiatives.
- **EPR Credit Facilitation:** Enable producers to meet compliance by supporting city-level waste processing, earning credits under national EPR frameworks.

5. Innovation, Research, and Digitalization Incentives

Objective: Encourage CE innovation, data-driven planning, and research collaboration.

- **Startup and Incubation Support:** The policy Supports seed funding, expert mentorship, and pilot project opportunities to innovative circular economy startups, such as those developing AI-powered waste sorting technologies or plastic-to-fuel conversion systems, fostering scalable solutions in sustainable

urban waste management.

- **Municipal-Academic Grants:** Funding is allocated to collaborative research projects between universities and Urban Local Bodies (ULBs), enabling in-depth studies of urban circular economy models, identifying best practices, and developing context-specific solutions to enhance sustainable solid waste management in cities.

- **Open Data Policy:** Municipalities rewarded for publishing transparent, real-time waste data through dashboards and public portals.

6. Behavioral Change and Public Engagement Incentives

Objective: Build long-term community involvement and CE mindset through education and media.

- **School-Based Curriculum Grants:** Schools integrating circular economy (CE) modules and project-based learning focused on waste management receive financial assistance to develop curriculum materials, conduct workshops, and organize community initiatives, fostering early awareness and practical skills among students for sustainable urban waste practices.

- **Creative Campaign Funding:** Grants support NGOs, artists, and media groups in producing awareness campaigns using plays, street art, and short films, effectively engaging communities and promoting circular economy principles in urban solid waste management.

- **Community Rewards:** Monthly performance-based incentives for local resident welfare associations (RWAs) maintaining composting units or recycling hubs.

Institutional, Implementation & Governance Framework

1. Nodal Agency & Institutional Setup

- **Primary Nodal Agency:**
  The **State Urban Development Department (SUDD)** or the **Smart City Mission Cell** will act as the central coordinating body responsible for policy oversight, resource mobilization, and inter-agency coordination.

- **Supporting Institutions:**

    - **Urban Local Bodies (ULBs):** Responsible for on-ground implementation, monitoring, community engagement, and reporting.

    - **Waste Management Authorities (WMAs):** Specialized units within ULBs focusing on technical aspects such as infrastructure development, data collection, and partnerships.

- **State Pollution Control Board (SPCB):** Regulatory oversight on environmental standards and compliance.
- **Informal Sector Cooperatives:** Recognized bodies representing informal workers, ensuring their integration and welfare.
- **Research and Academic Institutions:** Partner for ongoing innovation, monitoring, and capacity building.
- **NGOs and Civil Society:** Facilitate awareness, training, and community participation.

2. Implementation Mechanism

- **Phase-wise Rollout:**
  Implementation will be structured in phases:
  - **Pilot Phase:** Specific city zones are selected based on demographic diversity, waste generation patterns, and existing infrastructure to pilot incentive programs and circular economy infrastructure, allowing tailored testing and refinement before broader implementation.
- **Scaling Phase:** Expansion based on pilot results and capacity building.
- **Full Implementation:** City-wide adoption and continuous improvement.
- **Capacity Building & Training:**
  Regular training programs for ULB staff, informal workers, and private partners on circular economy principles, technology use, and incentive management.
- **Stakeholder Engagement:**
  Establish multi-stakeholder committees at city and ward levels, including citizen representatives, to ensure participatory governance and feedback loops.
- **Digital Infrastructure:**
  Deployment of integrated digital platforms for tracking waste segregation, incentive distribution, and real-time monitoring.

3. Governance and Monitoring Framework

- **Key Performance Indicators (KPIs):**
  Monitoring based on clear KPIs, including:
  - Percentage of households segregating waste correctly.
  - Volume and quality of recyclables and compost generated.
  - Number of informal workers formalized and trained.
  - Reduction in landfill waste and carbon emissions.

- **Data Transparency:**
  Mandatory public disclosure of performance data through open dashboards to encourage accountability and citizen trust.

- **Incentive Disbursement Audits:**
  Regular independent audits review the distribution and utilization of incentives, ensuring transparency, preventing fraud or misuse, and promoting fair, equitable access to benefits across all stakeholders in the circular waste management system.

- **Policy Review Committee:**
  A committee consisting of government officials, experts, civil society, and private sector representatives to periodically review policy effectiveness and recommend adjustments.

4. Funding & Resource Mobilization

- **Multi-Source Funding Pool:**
  Combine resources from:

    - **Municipal Budgets:** Dedicated budget allocations cover operational and maintenance expenses for circular waste management facilities, ensuring consistent functionality, timely repairs, and sustainable service delivery throughout the infrastructure's lifespan.

    - **Central Government Schemes:** Leverage programs like Swachh Bharat Mission (SBM 2.0).

    - **Green Bonds & Climate Funds:** Access international and domestic green financing mechanisms.

    - **Corporate Social Responsibility (CSR):** Promote corporate investment in community-based circular economy projects and infrastructure through incentives, recognition programs, and partnership opportunities, fostering shared responsibility and strengthening public-private collaboration in sustainable urban waste management.

    - **Public-Private Partnerships (PPP):** Mobilize private capital through incentives and viability gap funding.

- **Financial Management:**
  Establish a dedicated **Circular Economy Waste Management Fund** within the municipal treasury to streamline fund allocation and reporting.

This comprehensive policy framework ensures that all key stakeholders—citizens, informal workers, private players, and institutions—are incentivized to participate meaningfully in the development of a circular urban solid waste management system.

9.2 Strategies & Proposals

Integrating AI, Technology & IoT in Circular Economy for Urban Solid Waste Management

1. Introduction

The growing urban population generates increasing volumes of solid waste, posing environmental, economic, and social challenges. Transitioning to a circular economy (CE) model emphasizes waste minimization, resource recovery, and sustainable management. Emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and smart devices provide innovative tools to optimize urban solid waste management (USWM), enabling real-time monitoring, predictive analytics, and efficient resource utilization.

2. Objectives

- Utilize AI for predictive waste generation modeling and optimization of collection schedules.
- Deploy IoT-enabled smart bins and sensors to enhance segregation, monitoring, and reduce overflow.
- Implement AI-powered automated sorting and characterization to maximize recovery of recyclables and organics.
- Develop technology-driven citizen engagement platforms to promote behavioral change and participation.
- Establish data-driven decision-support systems for policymakers and stakeholders.
- Facilitate integration of informal waste workers into formal, tech-supported circular systems.

3. Key Components

A. IoT Infrastructure and Smart Waste Collection

- **Smart Waste Bins**: Smart bins are equipped with advanced sensors that detect fill levels, waste types, and contamination. This real-time data is transmitted to centralized systems to optimize waste collection routes and schedules dynamically.
- **Vehicle Tracking**: GPS and RFID-based tracking of waste collection vehicles to

optimize routes, reduce fuel consumption, and ensure timely service.

- **Centralized Monitoring Dashboard**: Real-time dashboards provide municipal authorities with instant updates on bin fill levels, contamination, and collection status, enabling swift responses, improved resource allocation, and more efficient urban waste management operations.

B. AI-Driven Waste Sorting and Resource Recovery

- **Machine Learning Algorithms**: For automated identification and segregation of waste materials via computer vision systems in Material Recovery Facilities (MRFs).

- **Waste Composition Analysis**: AI models analyze real-time and historical waste data to forecast processing needs, dynamically adjust sorting operations, reduce residuals sent to landfills, and ensure maximum recovery of recyclable and compostable materials.

- **Optimization Models**: AI models analyze real-time and historical waste data to forecast processing needs, dynamically adjust sorting operations, reduce residuals sent to landfills, and ensure maximum recovery of recyclable and compostable materials.

C. Citizen Engagement and Incentive Systems

- **Mobile Applications**: AI-powered mobile apps guide residents on correct waste segregation through interactive tutorials, offer instant feedback on sorting errors, and monitor individual or community participation levels to encourage consistent, responsible waste behavior.

- **Gamification and Rewards**: Points and incentives for households demonstrating effective segregation and participation in community composting.

- **Behavioral Analytics**: AI systems process user interaction and behavior data from apps and platforms to identify patterns, enabling the creation of personalized awareness campaigns that effectively promote waste segregation and circular lifestyle habits.

D. Data Analytics and Decision Support

- **Integrated Data Platforms**: Aggregating data from IoT devices, citizen apps, and processing units forms the backbone of a smart and efficient Circular Economy (CE) model in urban solid waste management.

  IoT devices, citizen apps, and processing units feed real-time data into a centralized AI platform, enabling predictive analytics, optimized operations, and enhanced transparency for smarter, circular urban solid waste management.

- **Predictive Analytics**: AI and data analytics are used to forecast waste generation peaks by analyzing historical trends, population growth, seasonal variations, and consumption patterns. This predictive capability allows municipal authorities to anticipate high-demand periods—such as festivals or monsoon seasons—and allocate resources like manpower, vehicles, and processing capacity accordingly. Proactive planning based on these forecasts helps prevent service delays, reduces overflow incidents, and ensures that infrastructure such as composting units or MRFs operates at optimal efficiency. Ultimately, this approach enhances the resilience and responsiveness of the circular waste management system.

- **Performance Monitoring**: KPIs for segregation rates, material recovery, greenhouse gas emissions, and operational efficiency.

Operational Efficiency

- **Waste Collection Efficiency (%)**
  Ratio of timely collections to total scheduled pickups.

- **Smart Bin Fill-Level Accuracy (%)**
  Accuracy of sensor data compared to actual waste volume.

- **Route Optimization Savings (%)**
  Reduction in fuel and time due to dynamic route planning.

Environmental Impact

- **Waste Diversion Rate (%)**
  Proportion of waste diverted from landfills through reuse, recycling, and composting.

- **Reduction in Greenhouse Gas Emissions (kg CO_2e)**
  Measured reduction from improved waste handling and processing.

- **Composting and Recycling Rates (%)**
  Amount of organic and recyclable waste successfully processed.

Citizen Engagement

- **User Participation Rate (%)**
  Number of active users in apps and segregation programs.

- **Segregation Compliance Rate (%)**
  Proportion of households/institutions consistently segregating waste correctly.

- **Reward Redemption Rate (%)**
  Engagement level with digital incentive schemes.

Economic Efficiency

- **Cost per Tonne of Waste Processed (₹/tonne)**
  Operational cost efficiency of CE interventions.

- **Revenue from Recovered Resources (₹)**
  Earnings from recyclables, compost, or energy generation.
  Return on Investment (ROI) for Tech Deployment (%)
  Financial benefits relative to costs of AI/IoT systems.

Social Impact

- **Informal Worker Inclusion Rate (%)**

  Percentage of informal waste workers integrated into formal systems.

- **Training Completion Rate (%)**
  Number of workers/officials completing capacity-building programs.

- **Health and Safety Incidents (per month)**
  Frequency of accidents or health issues reported among waste handlers.

4. Implementation Plan

- **Pilot Phase**: **Criteria for Zone Selection**

1. **High Waste Generation Areas**
   Prioritize commercial hubs, dense residential zones, and institutional areas with high daily waste output.

2. **Low Segregation Compliance**
   Target zones where current waste segregation levels are poor to drive behavioral change through technology and incentives.

3. **Existing Infrastructure Gaps**
   Select areas lacking adequate waste monitoring or processing infrastructure for smart upgrades.

4. **Citizen Engagement Potential**
   Choose communities with active resident welfare associations (RWAs), schools, or NGOs open to digital participation and pilots.

5. **Ease of Monitoring and Access**
   Zones with good connectivity and accessibility for waste vehicles and tech maintenance teams.

- **Stakeholder Collaboration**: Engage ULBs, private recyclers, informal workers, technology providers, and communities.

- **Training Programs**: Capacity building is essential to ensure successful adoption and sustained impact of technology-driven circular economy models in urban solid waste management. Training programs should be designed for three key groups:

1. **Municipal Staff**
   Workshops on operating AI-powered dashboards, interpreting IoT data, and managing digital systems for waste collection and processing. Emphasis on decision-making using real-time analytics and monitoring KPIs.

2. **Waste Workers**
   Hands-on training in using smart tools (e.g., sensors, mobile apps), safe handling practices, and segregation techniques. Skill development in operating or supporting AI sorting equipment and understanding circular waste processes.

3. **Community Leaders**
   Sessions to equip local influencers with knowledge on promoting technology adoption among residents, organizing awareness drives, and facilitating feedback loops through citizen apps.

- **Data Privacy & Security**: Implementing protocols for ethical data collection and use in circular economy models for urban solid waste management involves several critical steps:

1. **Informed Consent:**
   Ensure all participants—residents, waste workers, and stakeholders—are fully informed about what data is collected, how it will be used, and their rights, obtaining explicit consent before data collection.

2. **Data Privacy and Anonymity:**
   Design systems to anonymize personal information, protecting identities while allowing meaningful analysis. Follow data protection regulations (e.g., GDPR principles) to safeguard user privacy.

3. **Transparency:**
   Maintain clear communication about data collection purposes, storage methods, and sharing policies. Provide accessible channels for stakeholders to ask questions or withdraw consent.

4. **Data Security:**
   Employ robust cybersecurity measures to prevent unauthorized access, breaches, or misuse of sensitive information across IoT devices, apps, and databases.

5. **Purpose Limitation:**
   Use collected data solely for intended purposes related to improving waste management and circular economy goals, avoiding secondary or commercial exploitation without further consent.

6. **Equity and Non-Discrimination:**
   Ensure data practices do not reinforce biases or exclude marginalized groups, promoting inclusive participation and benefit-sharing.

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