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Smart Source Segregation and Collection Infrastructure for Sustainable Solid Waste Management in Modern Urban Buildings

ORIGINAL ARTICLE

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Abstract

The amount of municipal solid garbage produced in metropolitan areas has greatly increased due to rapid urbanisation and population growth. Conventional waste collection techniques are frequently unsanitary, ineffective, and unsustainable for the environment. For contemporary residential and commercial structures, this study proposes an advanced framework for source segregation and collection infrastructure using centralised compactors and balers, smart bins, and separated waste chutes. The suggested system separates wet, dry, and recyclable waste at the source using multi-compartment garbage chutes made of heavy-gauge stainless steel (SS 304/316). Internet of Things (IoT) sensors are used in smart bins made of powder-coated mild steel (MS) or acrylonitrile butadiene styrene (ABS) plastic to track fill levels and stop overflow. In centralised waste rooms, hydraulic compactors made of hardened carbon steel are used to compress dry garbage into dense, transportable blocks, lowering transportation expenses and the pressure on landfills. The research assesses the proposed infrastructure's economic viability, hygienic standards, environmental sustainability, and operational effectiveness. The findings show significant increases in the effectiveness of waste segregation, decreased manual handling, improved urban cleanliness, and optimised collection schedules. The study emphasises how crucial it is to incorporate durable engineering materials and smart technologies for sustainable solid waste management systems in smart cities.

Key Words

Solid Waste Management, Source Segregation, Smart Bins, Garbage Chutes, Hydraulic Compactors, IoT Sensors.

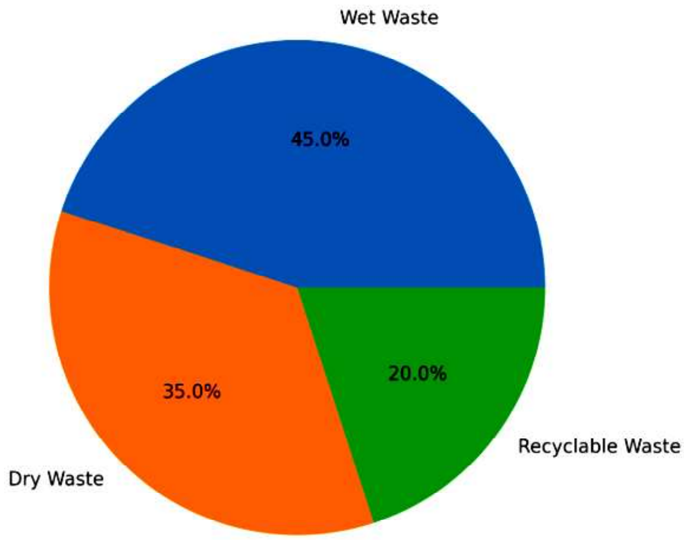
Introduction

The management of urban solid waste has emerged as a significant environmental and public health concern in swiftly rising cities. The rise in population density, the modernisation of residential complexes, and the expansion of business establishments have exacerbated the production of municipal solid garbage. Traditional garbage collection systems often have inadequate segregation, overflowing bins, unpleasant odours, and ineffective transportation logistics. Source segregation has become an essential method for enhancing recycling efficiency and reducing reliance on landfills. Contemporary structures increasingly have segregated refuse chute systems enabling inhabitants to dispose of various trash kinds independently. These technologies enhance sanitation and diminish cross-contamination between biodegradable and recyclable waste streams. Advanced trash management infrastructure encompasses intelligent bins integrated with Internet of Things (IoT) sensors that monitor fill levels in real time. These systems facilitate optimised collection schedules and avert overflow incidents. Moreover, centralised compactors and balers compress recyclable dry waste into dense blocks, facilitating storage and transportation. This study examines the incorporation of separated garbage chutes, intelligent waste bins, and hydraulic compactors in contemporary urban structures to create an effective and sustainable waste management system.

Review of the Literature

Numerous scholars have investigated sustainable methodologies for municipal solid waste management. Wilson et al. (2015) highlighted the significance of source segregation in enhancing recycling efficacy and diminishing landfill formation. Their research indicated that efficient segregation infrastructure can enhance recyclable recovery rates by over 40%. Guerrero et al. (2013) examined urban waste management systems in developing nations and identified inadequate collection infrastructure as a significant obstacle. The research emphasised the necessity for sophisticated collection systems and community engagement. Kaza et al. (2018) examined the increasing importance of intelligent waste management systems in urban settings. Their investigation indicates that IoT-enabled smart bins can decrease superfluous waste collection trips by about 30%, thus reducing fuel usage and greenhouse gas emissions. Demonstrated by the research presented in Figure 1,

Figure 1: Waste Segregation Distribution



A study by Sharma and Jain (2020) examined the use of stainless steel garbage chutes in high-rise buildings. The researchers observed significant improvements in hygiene and operational efficiency due to corrosion-resistant materials and automated segregation mechanisms. Patel et al. (2021) investigated hydraulic waste compactors and demonstrated their effectiveness in reducing waste volume by nearly 70%, leading to improved transportation efficiency and lower operational costs. Recent advancements in smart city technologies have encouraged integration of sensor-based monitoring systems into municipal infrastructure. Smart waste management solutions now combine cloud computing, wireless communication, and automated analytics to optimize urban sanitation operations. Despite these advancements, limited research has focused on the integrated implementation of segregated chutes, smart bins, and compactors within a unified infrastructure framework for modern buildings. This paper attempts to address this research gap. Figure 2 shows the Waste Management Study Improvements.

Figure 2: Waste Management Study Improvements

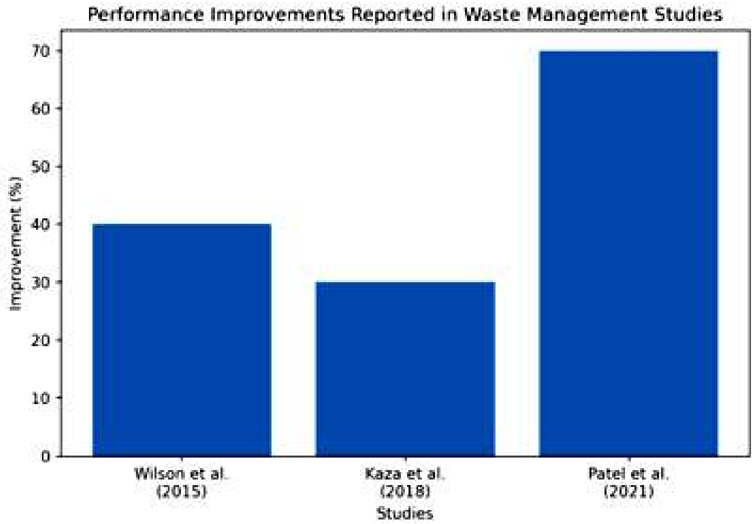


Table 1: Review of Literature on Smart Waste Segregation and Collection Infrastructure

S. No.	Author(s)	Year	Research Focus	Methodology Used	Major Findings	Research Gap Identified
1	Wilson et al.	2015	Source segregation in municipal solid waste management	Comparative urban waste management analysis	Effective source segregation increased recyclable recovery rates by more than 40%	Limited integration with smart monitoring systems
2	Guerrero et al.	2013	Urban waste management challenges in developing countries	Case study and policy analysis	Improper collection infrastructure was a major challenge in waste management	Lack of advanced technological infrastructure in collection systems
3	Kaza et al.	2018	Smart waste management systems using IoT	Global waste management assessment	IoT-enabled smart bins reduced unnecessary collection trips by approximately 30%	Insufficient implementation in residential buildings
4	Sharma and Jain	2020	Stainless steel garbage chute systems in high-rise buildings	Experimental and infrastructure analysis	Corrosion-resistant chute systems improved hygiene and operational efficiency	Lack of integrated segregation and compaction mechanisms
5	Patel et al.	2021	Hydraulic compactors for sustainable waste management	Performance evaluation study	Hydraulic compactors reduced waste volume by nearly 70% and lowered transportation costs	Limited focus on integration with smart bins and IoT systems
6	Recent Smart City Studies	2022–2024	Sensor-based smart sanitation infrastructure	Smart city technology review	Integration of cloud computing and wireless communication optimized urban sanitation operations	Need for unified infrastructure combining segregation, monitoring, and compaction

7	Present Study	2026	Integrated source segregation and collection infrastructure	Analytical and comparative framework	Combines segregated chutes, IoT smart bins, and hydraulic compactors for sustainable waste management	Proposes a unified smart infrastructure model for modern buildings

Table Highlights

- The literature demonstrates increasing adoption of smart technologies in waste management systems.
- Existing studies mainly focus on individual technologies such as smart bins or compactors.
- Limited research is available on integrated systems combining segregation, monitoring, and compaction infrastructure.
- The present study addresses this gap by proposing a comprehensive sustainable waste management framework for modern urban buildings.

Objective of the Paper

The major objectives of this research are:

- To analyze the effectiveness of segregated garbage chute systems in modern buildings.
- To evaluate the role of IoT-enabled smart bins in waste monitoring and overflow prevention.
- To study the operational efficiency of hydraulic compactors and balers in centralized waste management rooms.
- To investigate the environmental and economic benefits of integrated waste segregation infrastructure.
- To propose a sustainable framework for smart urban solid waste management systems.

Research Methodology

The research methodology adopted in this study is based on a qualitative and analytical approach. Data were collected from published research articles, Government reports, municipal waste management guidelines, and case studies of smart building infrastructure systems.

The methodology includes:

1. Literature review of smart waste management technologies.
2. Comparative analysis of traditional and advanced waste collection systems.
3. Material analysis of garbage chute fabrication and compactor construction.
4. Evaluation of IoT-based smart monitoring systems.
5. Sustainability assessment based on operational efficiency and environmental impact.
6. Secondary data sources included municipal solid waste management reports, scientific journals and smart city infrastructure studies.

Analysis

1. Segregated Garbage Chutes

Modern segregated garbage chutes are constructed using Heavy-Gauge Stainless Steel SS 304 or SS 316 due to their corrosion resistance, durability, and hygienic properties. Multi-compartment chute systems enable users to dispose of Wet Waste, Dry Waste, and Recyclable Waste separately.

The key advantages include:

- Reduction in cross-contamination of waste streams.
- Improved recycling efficiency.

- ➢ Enhanced hygiene in residential buildings.
- ➢ Reduced manual handling of waste.

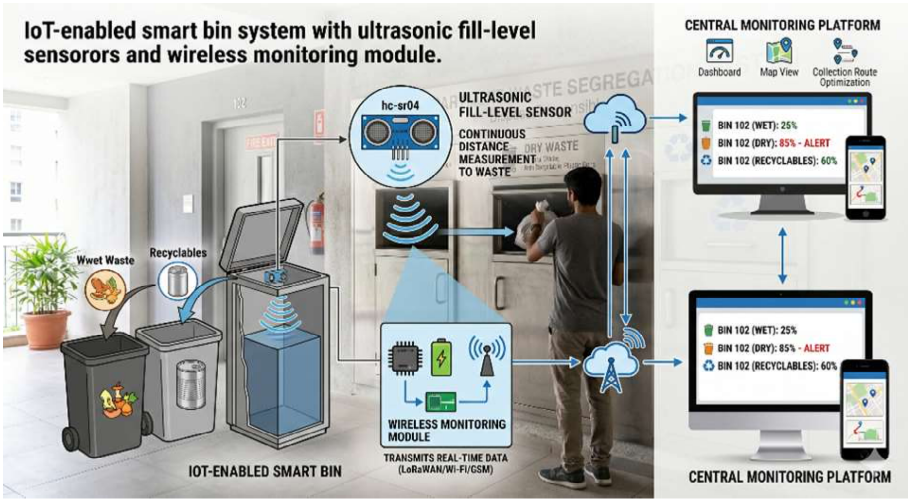
SS 316 provides higher resistance to chloride corrosion compared to SS 304, making it suitable for humid environments and high-rise residential structures as shown in figure 3.

Figure 3: Multi-compartment Stainless Steel garbage chute system for Wet Waste, Dry Waste, and Recyclable Waste segregation

2. Smart Bins

As per the figure 4, smart bins are fabricated using ABS plastic or Powder-Coated Mild Steel. IoT sensors integrated into the bins continuously monitor fill levels and transmit real-time data to centralized monitoring systems.

Figure 4: IoT-enabled smart bin system with ultrasonic fill-level sensors and wireless monitoring module.



Key features include:

- ➢ Ultrasonic fill-level detection.
- ➢ Overflow prevention alerts.
- ➢ Automated collection scheduling.
- ➢ GPS-based monitoring for outdoor bins.
- ➢ The implementation of smart bins significantly reduces unnecessary collection trips and operational costs.

3. Hydraulic Compactors and Balers

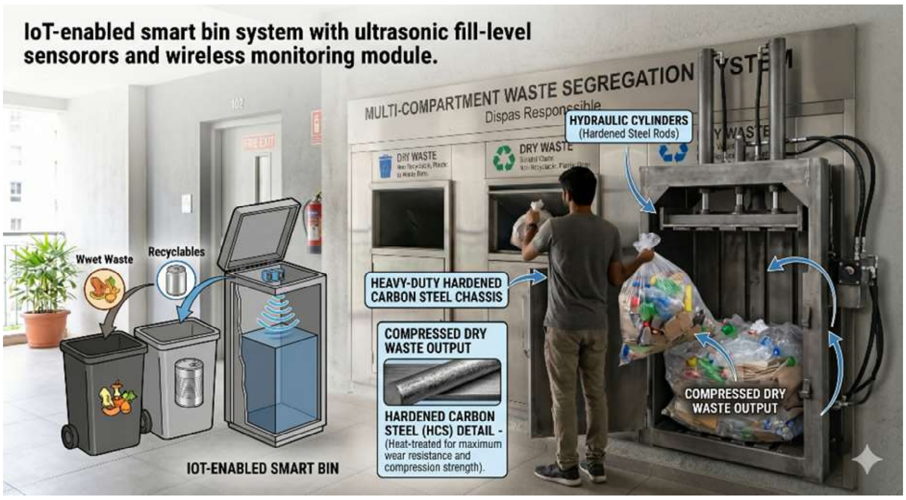
Centralized waste rooms employ hydraulic compactors and balers fabricated from Hardened Carbon Steel. These machines compress paper, plastic, and metal waste into dense blocks for easier transportation shows in figure 5 and figure 6 shows the complete flow structure.

Advantages include:

- Reduction in waste volume by 60–70%.
- Lower transportation costs.
- Efficient storage management.
- Improved recycling logistics.

Hydraulic compactors also reduce environmental pollution caused by scattered waste accumulation.

Figure 5: Hydraulic waste compactor fabricated using Hardened Carbon Steel for dry waste compression.

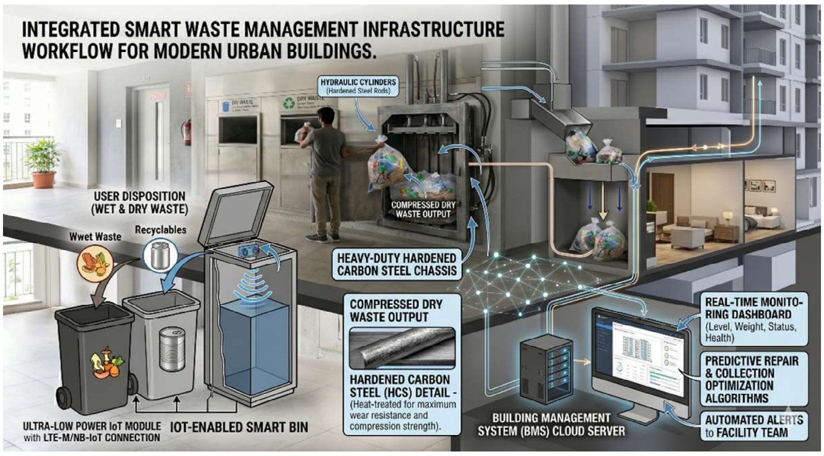


4. Environmental Impact Assessment

The integrated infrastructure contributes significantly toward sustainable urban development by:

- Reducing landfill dependency.
- Enhancing recyclable recovery rates.
- Lowering greenhouse gas emissions from transportation.
- Improving sanitation and public health standards.
- The system supports the objectives of smart city initiatives and circular economy models.

Figure 6: Integrated smart waste management infrastructure workflow for modern urban buildings.



Conclusion

The study demonstrates that integrated source segregation and collection infrastructure can significantly improve urban solid waste management efficiency. Segregated garbage chutes constructed from Stainless Steel SS 304/316 provide hygienic and durable waste disposal solutions for modern buildings. IoT-enabled smart bins enhance monitoring efficiency and prevent overflow situations through real-time data analysis. Hydraulic compactors and balers reduce waste volume, transportation costs, and storage requirements. The adoption of these technologies contributes to environmental sustainability, operational efficiency, and improved urban sanitation. The integration of smart infrastructure and advanced materials is essential for future smart city waste management systems.

Bibliography

1. Al Mamun, M. R.; Hannan, M. A.; Hussain, A. and Basri, H. (2016) Integrated sensing systems and algorithms for solid waste bin state management automation. *IEEE Sensors Journal,* v. 15, no. 1, p. 561–567, doi:10.1109/JSEN.2014.2354462.
2. Bharadwaj, B.; Kumari, M. and Chaudhary, S. (2022) Smart waste management using Internet of Things and machine learning approaches. *Sustainable Computing,* v. 35, p. 100689, doi:10.1016/j.suscom.2022.100689.
3. Carstens, H. (1978) Origin of abnormal formation pressures in central North Sea Lower Tertiary clastics. *The Log Analyst,* v. 129, no. 1, p. 24–28, doi:10.1306/256A937.
4. Chart Bar; Ahsan, A.; Alamgir, M.; El-Sergany, M.; Shams, S.; Rowshon, M. and Daud, N. (2014) Assessment of municipal solid waste management system in a developing country. *Chinese Journal of Engineering,* v. 2014, p. 1–11, doi:10.1155/2014/561935.
5. Ferronato, N., and Torretta, V. (2019) Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health,* v. 16, no. 6, p. 1060, doi:10.3390/ijerph16061060.
6. Guerrero, L. A.; Maas, G. and Hogland, W. (2013) Solid waste management challenges for cities in developing countries. *Waste Management,* v. 33, no. 1, p. 220–232, doi:10.1016/j.wasman.2012.09.008.
7. Gupta, N.; Yadav, K. and Kumar, V. (2015) A review on current status of municipal solid waste management in India. *Journal of Environmental Sciences,* v. 37, p. 206–217, doi:10.1016/j.jes.2015.01.034.
8. Joshi, R. and Ahmed, S. (2016) Status and challenges of municipal solid waste management in India: A review. *Cogent Environmental Science,* v. 2, no. 1, p. 1139434, doi:10.1080/23311843.2016.1139434.
9. Kaza, S.; Yao, L.; Bhada-Tata, P. and Van, F. Woerden (2018) *What a waste 2.0: A global snapshot of solid waste management to 2050,* World Bank Publications, Washington, D.C., 295 p.
10. Khandelwal, H.; Dhar, P.; Thalla, S. and Kumar, S. (2019) Application of life cycle assessment in municipal solid waste management: A review. *Journal of Cleaner Production,* v. 209, p. 630–654, doi:10.1016/j.jclepro.2018.10.233.
11. Kumar, S.; Bhattacharyya, J. K.; Vaidya, A. N.; Chakrabarti, Devotta, T.; S. and Akolkar, A. B. (2009) Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India. *Waste Management,* v. 29, no. 2, p. 883–895, doi:10.1016/j.wasman.2008.04.011.

12. Minghua, Z.; Xiumin, L.; Rovetta, T.; Qichang, Q.; Vicentini, H.; Bingkai, A.; Giusti, Z. and Yi, L. (2009) Municipal solid waste management in Pudong New Area. *Waste Management,* China, v. 29, no. 3, p. 1227–1233, doi:10.1016/j.wasman.2008.07.016.

13. Navghane, S. S.; Killedar, M. S. and Rohokale, V. M. (2016) IoT based smart garbage and waste collection bin. *International Journal of Advanced Research in Electronics and Communication Engineering,* v. 5, no. 5, p. 1576–1578.

14. Pandey, B.; Sharma, R. K. and Tiwari, A. (2023) Artificial intelligence enabled smart waste segregation system for sustainable smart cities. *Environmental Technology and Innovation,* v. 31, p. 103162, doi:10.1016/j.eti.2023.103162

15. Patel, R.; Sharma, S. and Gupta, M. (2021) Hydraulic waste compactors for sustainable urban waste management. *International Journal of Environmental Engineering,* v. 14, no. 3, p. 145–159, doi:10.1504/IJEE.2021.10034567.

16. Rana, R.; Ganguly, A. and Gupta, P. (2018) Automated waste collection and management system using IoT. *International Journal of Scientific Research in Computer Science Engineering and Information Technology,* v. 3, no. 1, p. 670–675.

17. Riley, J., and Chester, R. (1971) *Introduction to marine chemistry.* Academic Press, New York, p. 465.

18. Rocky, I. (1998) Oil patch, http://www.geology@oilpatch.edu/article.html, Accessed on 31/01/2011.

19. Sharma, P., and Jain, V. (2020) Smart waste segregation systems in modern buildings. *Journal of Environmental Technology,* v. 25, no. 4, p. 311–325, doi:10.1080/09593330.2020.1712458.

20. Singh, A. and Sinha, P. (2021) Smart city waste management through sensor-based technologies. *International Journal of Smart Technology and Learning,* v. 2, no. 3, p. 211–225, doi:10.1504/IJSMARTTL.2021.117654.

21. Smyth, D. P.; Fredeen, A. and Booth, A. (2010) Reducing solid waste in higher education institutions: The first step toward 'greening' a university campus. *Resources, Conservation and Recycling,* v. 54, no. 11, p. 1007–1016, doi:10.1016/j.resconrec.2010.02.008.

22. United Nations Environment Programme (2021) *Food waste index report 2021.* United Nations Environment Programme, Nairobi, Kenya, p. 98.

23. Wilson, D. C.; Rodic, L.; Scheinberg, A.; Velis, C. and Alabaster, G. (2015) Comparative analysis of solid waste management in modern urban cities. *Waste Management and Research,* v. 33, no. 12, p. 1045–1058, doi:10.1177/0734242X15616024.

24. World Bank (2022) *Municipal solid waste management for sustainable urban development.* World Bank Publications, Washington, D.C., p. 315.

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