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Circular Economy Approaches in Municipal Solid Waste Management: Progress, Challenges, and Future Perspectives

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Abstract

Municipal solid waste (MSW) generation has increased rapidly because of urbanization, population growth, and changing consumption patterns, creating significant environmental, economic, and social challenges for cities worldwide. This review examines the role of circular economy approaches in transforming conventional waste management into resource-efficient systems that prioritize waste prevention, material recovery, recycling, reuse, and value retention. The article synthesizes recent advances in circular waste management strategies, including source segregation, recycling, biological treatment, waste-to-energy technologies, and resource recovery, while highlighting the contribution of emerging digital technologies such as artificial intelligence, the Internet of Things, cloud computing, digital twins, and smart communication systems in improving operational efficiency and decision-making. The review further evaluates the environmental, economic, and social benefits associated with circular municipal waste management, including reduced greenhouse gas emissions, resource conservation, green employment, and enhanced community participation. In addition, it discusses the importance of policy frameworks, extended producer responsibility, collaborative governance, and multi-stakeholder partnerships in supporting successful implementation. Persistent barriers, including inadequate infrastructure, financial constraints, fragmented governance, technological limitations, and behavioral challenges, are also critically examined. Finally, the review identifies future directions focused on eco-innovation, smart-city business models, digital transformation, and integrated governance to strengthen circular municipal solid waste systems. Collectively, the findings demonstrate that adopting circular economy principles provides a practical pathway for improving resource efficiency, reducing environmental impacts, and supporting sustainable urban development while advancing long-term sustainability goals.

Keywords- *Circular economy, Municipal solid waste management, Resource recovery, Smart waste management, Sustainable urban development*

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1. INTRODUCTION

The generation of municipal solid waste (MSW) has significantly risen due to rapid urbanization, population growth, industrialization, and changing consumption patterns, putting immense pressure on the natural resources, public health and environmental systems globally. In many respects, conventional waste management has taken a linear economic approach with resource extraction, production, consumption and disposal, which has led to an increasing number of waste landfills, GHGs, resource depletion and environmental degradation. The difficulties encountered have shown the inadequacy of the traditional waste management and underlined the importance of more sustainable waste management solutions, such as keeping materials in the economy as long as possible and generating minimal waste. It is thus no surprise that the circular economy (CE) is now an emerging paradigm which aims to redefine production and consumption processes through a focus on resource usage, waste avoidance, reuse, recycling, recovery, and regeneration instead of landfilling (Ghosh & Ghosh, 2021; Wilson, 2023).

Cities are significant consumers and generators of waste and the concept of circular economy in MSWM is becoming more relevant. Circular approaches help to recover materials, energy and nutrients and minimize reliance on primary resources by seeing waste as a valuable secondary resource rather than a burden to the environment. These methods can help protect the environment and drive economic resilience by creating new business opportunities, green jobs and enhancing the productivity of the resources. Moreover, the circular economy has been recognised globally as a viable way of speeding up progress towards the Sustainable Development Goals (SDGs), especially SDG 11 on sustainable cities and local communities, SDG 12 on responsible consumption and production, SDG 13 on climate action and SDG 15 on life on land. The policy analyses in recent years have highlighted that circular resource management can breathe new life into the trajectory of progress towards the 2030 Agenda, connecting environmental, economic and social aspects (Schröder & Barrie, 2024; Borchardt et al., 2022; Shulla & Leal-Filho, 2023).

Technological innovation is growing increasingly important in the process of implementing circular systems of municipal solid waste management. New technologies like AI, digital twins, geospatial analytics, sensor networks, and immersive tools have emerged as a result of digital transformation and are being leveraged to better monitor, collect, sort, forecast, and plan waste infrastructure. These technologies help in making data-driven decisions, optimizing resource recovery processes, and improving the efficiency of operations in the smart city environment. Digital twins, specifically, offer a virtualised representation of physical waste management systems, allowing for real-time monitoring, prediction, and assessing various scenarios for more sustainable urban resource management (Ali et al., 2024). In the same way, AI and emerging digital technologies, as part of wider smart city applications, are still enhancing planning, operational management, and stakeholder engagement in the circular waste management arena, showing significant potential for future applications (Lucchi, 2025).

Although some progress has been made, the shift to a more circular approach to managing municipal solid waste (MSW) is still unevenly spread across regions, due to technological, financial, institutional, regulatory, and behavioural barriers. Policy priorities are quite distinct between developed and developing economies, and the effectiveness of policy implementation depends on governance structures, infrastructure availability, market incentives and public participation. Comparative analyses of circular economy policies among the United States, the European Union, and China provide examples of common policy goals and challenges to implementation in each region, which impacts long-term sustainability results (Sesay et al., 2025). This review builds on the above and explores how circular economy practices in MSWM have developed, analyzes recent technological and policy innovations, considers current issues for implementing circular economy, and outlines future directions that could help achieve more resilient, resource efficient and sustainable urban waste management practices.

2. Foundations of Circular Economy in Municipal Solid Waste Management

The shift from traditional waste management to circular municipal solid waste (MSW) management is a change in the process of production, consumption and recovery of resources. The circular economy (CE) is different from the traditional linear economy of "take–make–dispose": It encourages closed loop material flows, where products, materials and resources are kept in use for as long as possible. The purpose of this transition is to reduce waste and increase material efficiency by retaining the value as long as possible. The circular model thus transforms waste into a valuable secondary resource, which helps to achieve sustainable production and consumption systems (Rashid & Malik, 2023).

The 5R's, which stand for Reduce, Reuse, Recycle, Recover and Redesign, are the basic principles of the circular economy. The principle of reduction is to minimise the use of resources and the amount of waste produced from the very outset, and the principle of reuse is to prolong the life of a product by reusing it. Energy and material recovery takes place when energy or valuable material is recovered from waste that is not recyclable. Redesign adds to these by promoting the life cycle redesign of products and their packaging that is durable, reparable, recyclable, and resource efficient. Together, these principles help minimize environmental impacts and ensure the economic sustainability of the operation (Chiang et al., 2024). Additionally, recent industrial applications have highlighted the benefits of combining the structured 4R approaches with the production process, showing that it increases material efficiency, reduces emissions, and boosts the circulation of resources, thus strengthening the practical value of the circular production systems (Abbaslou et al., 2026).

To support the circular approach to municipal solid waste management, the waste hierarchy is the blueprint of waste management operations based on prevention, reuse, recycling, recovery and disposal. This prioritization highlights that waste prevention/ material recovery has more impact than landfill disposal on the environment and economy. In the municipal system, there are ways to separate sources, collect select, have recycling facilities and technologies that allow valuable materials to be re-inserted into production cycles. The importance of resource recovery has grown particularly because today, waste streams are filled with materials and energy that can be recovered, thereby substantially decreasing reliance on virgin resources and protecting the environment (Adenuga et al., 2020). Similarly, the multiple waste components recovery has been found to achieve better environmental results and economic benefits than the traditional disposal methods (Liang et al., 2022).

Efficient collection systems and governance mechanisms that incentivize source separation of materials also play a crucial role in the successful implementation of circular waste management. Collection strategies can affect the efficiencies of recycling, collection costs and the overall recovery rate. Evaluations of collection approaches show that optimized collection systems can significantly enhance circular resource use and decrease reliance on landfills, as well as the application of Zero Waste principles (Apaydin & Akçay Han, 2023). Moreover, international evaluations highlight the need to have coordinated policy frameworks, technological infrastructures, stakeholder involvement and long-term institutional commitment to combine the waste hierarchy with the concept of circular economy. This integration can help municipalities transition from traditional waste management practices to more sustainable resource management systems, which can provide environmental, economic, and social benefits (Awino & Apitz, 2024). CMSWM is a prioritized set of strategies that start with waste prevention and redesign, followed by reuse, recycling, recovery and least of all disposal, as summarized in Table 1. The contribution of each strategy towards resource conservation, retaining the value of materials and reducing landfill varies.

Table 1. Core circular economy strategies in municipal solid waste management

Circular strategy	Primary purpose	Application in MSW management	Expected outcome	Sources
Reduce	Prevent waste generation	Sustainable consumption, material-efficient production and reduced packaging	Lower resource use and waste volume	Rashid and Malik (2023); Chiang et al. (2024)
Reuse	Extend product life	Repair, redistribution, refurbishment and repeated use	Reduced demand for new products	Chiang et al. (2024)
Recycle	Return materials to production	Processing paper, plastics, metals and glass into secondary materials	Greater material recovery and lower virgin-resource demand	Awino and Apitz (2024); Liang et al. (2022)
Recover	Extract remaining value	Energy, fuel or nutrient recovery from residual and organic waste	Reduced landfill disposal and increased resource utilization	Adenuga et al. (2020); Liang et al. (2022)
Redesign	Improve product circularity	Designing products for durability, repairability and recyclability	Waste prevention across the product life cycle	Chiang et al. (2024); Abbaslou et al. (2026)

3. Circular Economy Strategies across the Municipal Solid Waste Value Chain

Implementing the circular economy in municipal solid waste (MSW) management calls for coordinated actions across the whole waste value chain, starting from waste generation to material recovery and reintegration of resources. To ensure the effectiveness of circular systems, waste needs to be minimised at source and valuable materials recovered as efficiently as possible through collection, segregation, biological treatment and valorisation. These inter-dependent strategies include minimizing reliance on landfill, enhance resource productivity and sustain cities.

The quality and quantity of recoverable materials is the result of an efficient collection and transportation system, which is the building block for circular municipal waste management. A well-designed collection network, optimized transportation routes and stream separation prevent contamination and enhance downstream recycling and recovery. Nowadays, collection systems are increasingly adopting source-specific collection techniques and the optimization of logistics to increase the efficiency of such systems and minimize waste transport related environmental impacts (Nawar et al., 2024).

Household and community source separation is also a key factor to high material recovery rates. Pre-sorting waste into recyclable, organic and residual waste before collection ensures the quality of the waste and makes it easier to recycle at recycling plants and biologically treat at biological treatment plants. Household behaviour is a key driver of contamination levels and recycling outcomes and public participation is a determining factor for the success of segregation schemes. Policies and practices that focus on environmental awareness and accessibility of the recycling system have been found to have a significant impact on source separation practices and long-term participation in circular waste systems (Yu et al., 2022). These outcomes can be further reinforced by conducting educational and awareness campaigns, and providing practical guidelines for segregation, which will encourage more responsible waste management behavior among urban dwellers (Boonsema & Gains, 2023).

Organic wastes are one of the largest component of municipal solid wastes and are a significant opportunity for circular resource recovery. Anaerobic digestion and composting processes convert biodegradable waste to valuable products (compost, biofertilizers and renewable biogas) that help to minimize GHGs and return nutrients to agricultural systems. In recent years, the standard treatment approaches have been extended with the concept of integrated biorefineries in order to obtain higher added value bio-based products and satisfy the ideas of circular economy and circular bioeconomy. Adapting current composting and anaerobic digestion plants with solid-state fermentation technologies shows great potential to enhance resource efficiency and boost economic value in the treatment of organic waste (Artola et al., 2024).

In addition, integrated biological treatment systems, which integrate anaerobic digestion and composting, optimise energy recovery and nutrient recycling for a further increase in environmental sustainability. They can also help manage carbon, minimize landfill disposal and support renewable energy generation, and produce high-quality soil amendments that are appropriate for use in agriculture (Le Pera et al., 2022). Also, the use of biodegradable plastics has emerged as a new challenge to consider in organic waste handling. It has been shown that in some cases, the degradation of bioplastics can be achieved by anaerobic digestion, composting and subsequent soil degradation, the efficiency of which is, however, dependent on polymer composition and process conditions. These results emphasize the need for the development of compatible waste treatment technologies that can integrate new sustainable materials in a circular system for the treatment of municipal wastes (Cucina et al., 2021). An integrated approach to recovering waste streams into valuable materials and energy prior to re-entering the production and consumption process is the principle behind the closed-loop circular resource flow that is implemented in municipal solid waste management, as illustrated in Figure 1.

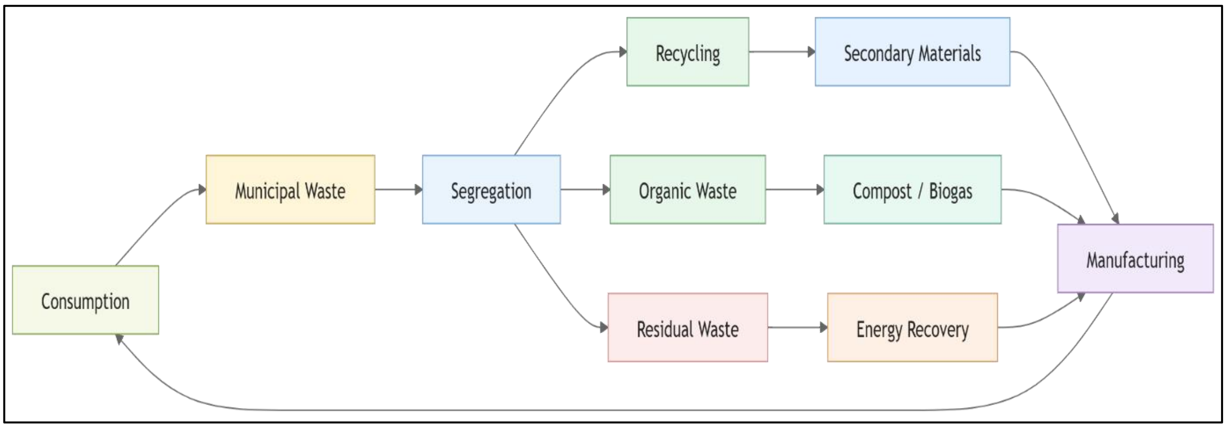

Figure 1. Closed-loop resource circulation in municipal solid waste management

4. Emerging Technologies Enabling Circular Municipal Solid Waste Management

Digital technologies are increasingly being used to boost the efficiency of operations, resource recovery, and decision-making based on data in the shift towards circular municipal solid waste (MSW) management. With the rise of urban population, there is a need for smart waste management solutions that can be used to optimize waste collection, track waste flows and maximize resource utilization. The use of artificial intelligence (AI), the Internet of Things (IoT), cloud computing, advanced communication networks and waste-to-energy technologies (WTE) have been instrumental in the implementation of circular economy principles by creating more efficient and sustainable ways to handle waste.

AI has turned out to be a vital technology to enhance several steps of the municipal waste value chain. The use of machine learning algorithms can allow the processing of vast amounts of operational data to forecast waste generation trends, improve collection planning, classify recyclable materials, and facilitate automated sorting systems. AI can also help with the predictive maintenance of waste management infrastructure, and even aid municipalities in resource allocation. Recent systematic analyses have shown that applications of AI can be important enablers to increase recycling rates, lower operating costs, enhance environmental performance, and make waste management systems more responsive, which are important factors of future circular cities (Singh et al., 2025).

The Internet of Things (IoT) also plays a vital role in strengthening the circular economy of waste management, by allowing a constant monitoring of the waste collection system with interconnected sensors and smart devices. Fitted with fill-level sensors, location tracking and environment sensing, smart bins provide real-time information that can be used to dynamically optimize collection routes, minimizing fuel use and unnecessary transport. These data streams are consolidated in a cloud-based platform, and organized into a centralized management system, enabling decisions based on evidence and maximizing resource recovery. This IoT and cloud-based waste management system has shown great potential to improve material reclamation, system transparency, and to facilitate Circular Resource Management (CRM) based on data (Farjana et al., 2023).

Smart waste management has also evolved with advanced communication technologies, enabling systems to be more powerful. Fifth-generation (5G) communication networks allow for the quick transfer of data from the sensors with minimal delay, which can help in real-time coordination among waste collection vehicles, monitoring devices, and centralized management systems. The use of smart waste management systems in 5G-enabled environments has shown increased responsiveness, higher collection efficiency, and better integration with the broader smart city systems, highlighting the potential of digital connectivity in sustainable waste management for smart cities (Longo et al., 2021).

In addition to digital innovations, waste-to-energy (WtE) technologies are still of great importance when it comes to circular management of municipal solid waste for the recovery of energy from waste fractions that are not recyclable, and therefore otherwise destined for landfilling. Modern WtE systems such as incineration with energy recovery, gasification, pyrolysis and anaerobic digestion, help to increase the resource efficiency by producing electricity, heat and alternative fuels, whilst decreasing the need for landfills. While material recycling is the preferred circular economy approach wherever possible, well-managed WtE technologies can be used to capture value from residual waste streams and support overall integrated approaches to circular economy. Evidence shows that the use of intelligent digital technologies alongside advanced resource recovery processes can significantly enhance the environmental sustainability and economic viability of modern municipal waste management systems (Boloy et al., 2021; Farjana et al., 2023). Table 2 compares the main functions and roundabout advantages of new waste-management technologies. These technologies enhance monitoring and forecasting, collection, sorting, material reclaiming and energy recovery, but need appropriate infrastructure, know-how and data systems.

Table 2. Emerging technologies supporting circular municipal solid waste management

Technology	Main application	Circular economy contribution	Key implementation consideration	Sources
Artificial intelligence	Waste forecasting, route optimization and automated sorting	Improves recycling accuracy and operational efficiency	Requires representative data and technical capacity	Singh et al. (2025)
Internet of	Smart-bin monitoring,	Prevents unnecessary	Depends on sensor	Farjana et

Things	fill-level detection and asset tracking	collection and improves material-flow monitoring	reliability and network coverage	al. (2023)
Cloud computing	Centralized data storage, analytics and decision support	Enables integrated and data-driven resource management	Requires secure and interoperable digital platforms	Farjana et al. (2023)
5G communication	Real-time transfer of sensor and vehicle data	Supports rapid coordination and responsive collection services	Requires advanced communication infrastructure	Longo et al. (2021)
Waste-to-energy systems	Conversion of residual waste into electricity, heat or fuel	Recovers value from non-recyclable waste and reduces landfill demand	Emission control and waste-hierarchy compliance are essential	Boloy et al. (2021)

5. Environmental, Economic, and Social Impacts of Circular Waste Management

Circular economy (CE) solutions for municipal solid waste (MSW) management have been seen to provide multi-dimensional benefits that address social, environmental and economic issues. However, circular systems focus on resource efficiency, pollution prevention and value recovery across the lifecycle of materials; being seen as a disposal problem is not the primary focus. The integrated outcomes contribute towards sustainable urban development to enhance municipal waste management systems resilience.

Environmentally, circular waste management greatly diminishes resource depletion, reliance on landfills and degradation of the environment through material reuse, recycling and resource recovery. Efficient process integration reduces waste in all stages of the production and consumption process, conserves natural resources and reduces environmental footprints. Sustainable system design also supports industrial symbiosis, cleaner production and pollution prevention and allows municipalities to move towards low-carbon and resource-efficient economy. Thus, waste management with a circular perspective plays a direct role in achieving environmental sustainability in the long run, leading to an improvement in overall resource productivity (El-Halwagi, 2025).

Circular waste management is also a key option to combat air pollution and climate change. More recycling, composting and valuable material recovery decreases the need for raw material extraction and energy intensive production processes, which decreases greenhouse gas emissions. Research on the evaluation of coordinated environmental policies shows that coordinated environmental policy measures that reduce pollution can have significant co-benefits, not only in improving air quality, but also in achieving climate mitigation targets (Cai et al., 2022). Analogously, there is evidence that synergies between emission reduction policies increase the environmental efficacy of the policies by implementing emission reduction in various pollutants through coordinated resource management and/or sustainable production system, therefore supporting the environmental value of the implementation of the circular economy. (Yang et al., 2022).

Economically, the circular municipal waste management offers opportunities for reuse of valuable materials, cost reduction and green innovation. The recovery of secondary raw materials reduces the reliance on primary materials and generates resilience and security in the raw material supply chain, and promotes the development of circular business models. Better resource efficiency allows to boost productivity and create jobs in recycling, remanufacturing, repair and resource recovery sectors. As a result, circular waste policies for municipalities can lead to enhancing environmental performance and long-term economic competitiveness.

The social aspect of circular waste management is also important, as stakeholders and communities are crucial to the implementation of all circular waste management strategies. Responsible waste segregation, recycling and acceptance of circular initiatives are facilitated by public awareness, transparent governance and collaborative decision making. Digital civic engagement platforms and open data systems also help facilitate communication between municipalities, citizens, and informal waste workers, increasing transparency and thus enabling more inclusive waste governance. These also acknowledge the role of the informal recycling sector, which can be integrated in the formal waste collection sector to lead to better material recovery, social inclusion and livelihoods (Hasselwander et al., 2022). In addition, community-based engagement models have shown that ongoing engagement of stakeholders helps to increase local ownership, to enhance behavior change and to facilitate the long-term success of integrated sustainability efforts. Such experiences underscore the need for reduced waste, more sustainable consumption and production practices, and enhanced cooperation and partnerships between the public and private sectors to achieve lasting environmental, economic, and social benefits through resilience circular waste management systems (Kabue et al., 2022). The interdependencies of environmental, economic and social impacts of circular waste management are illustrated in Figure 2 and highlight how resource recovery can contribute to sustainability, value creation and inclusive urban development.

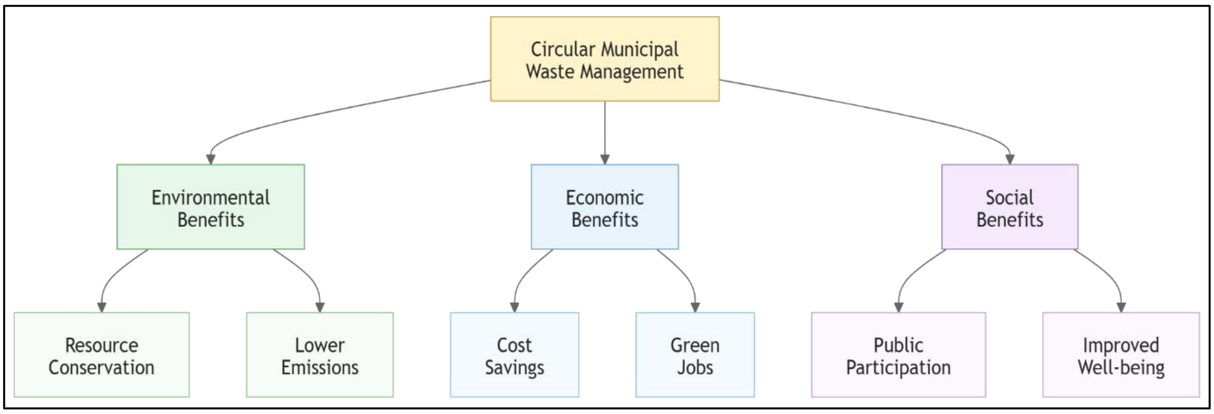

Figure 2. Triple-bottom-line impacts of circular waste management

6. Policy Frameworks, Governance, and Global Best Practices

In addition to technological innovations, strong policy frameworks, institutional governance and multi-stakeholder cooperation are all crucial for the transition to a circular economy (CE) in municipal solid waste (MSW). Governments are increasingly aware that to reach a circular economy, integrated regulatory measures are required, to foster resource efficiency, waste avoidance and to incentivize investments in sustainable waste management solutions. As a result, many countries have implemented legislative and policy measures to promote waste prevention, material recovery, and circular production and to integrate national strategies into overall sustainability goals.

Extended Producer Responsibility (EPR) is one of the most important policy instruments that promote circular waste management. EPR puts the responsibility to manage product life cycles—from collection to recycling to environmentally sound disposal—on producers after consumers use them. Recent innovations call for moving beyond the post-consumer waste management to pre-market producer responsibility, namely, for manufacturers to design durable, reparable, reusable and recyclable products before they are introduced to the market. This is a preventive strategy which will increase the circular flows of resources through reducing the amount of waste generated, and through increasing the sustainability of the product (Maitre-Ekern, 2021). In the same vein, modern approaches to the circular value chain highlight how modern EPR systems should bring together manufacturers, recyclers, consumers, and policy makers in a coordinated system which maximizes material recovery and minimises losses all along the value chain (Tong et al., 2024).

Experiences in various parts of the world show that the implementation of circular economy (CE) is highly unevenly spread across regions due to differences in economic development, capacity to govern, infrastructure and policy priorities. Existing regulatory frameworks and recycling infrastructure are more complete in developed countries, while many developing areas are still plagued by institutional and financial barriers. The quality of governance, economic conditions and institutional capacity plays an important role in the effectiveness of policy implementation, and it is important to consider the local contexts to which circular economy approaches are applied, as the one size fits all is not always applicable (Adeniyi & Dhaka, 2021).

Thus, good governance has become part of the essential elements of good circular management of municipal waste. The public administration continues to develop in a direction of cooperative governance, with an increasing focus on intergovernmental and inter-agency cooperation and coordination between government and private sector, academia, civil society and citizens. These governance mechanisms are effective in enhancing policy implementation, accountability and innovation through a blend of technical skills and stakeholder engagement (Temitope, 2023). Multi-stakeholder partnerships also help policies to be more effective, through mobilizing financial resources, promoting knowledge exchange and supporting collective action to achieve sustainable development goals. The partnerships are seen as necessary enablers that will help to realize sustainability targets as they bring together a variety of expertise and shared responsibilities between sectors (Momen, 2021; Eweje et al., 2021). Furthermore, public health interventions that have involved coordinated stakeholder engagement have been shown to enhance institutional resiliency, community trust, and sustainability of the interventions, providing a learning point for strengthening governance in the circular municipal solid waste management (MSWM) system (Ngoma et al., 2024). Producer responsibility, collaborative administration, multi-stakeholder partnerships, and a context-sensitive policy implementation, as presented in Table 3, are all key elements for ensuring effective circular waste governance. These mechanisms share the responsibility along the value chain and enhance accountability, resource mobilization, innovation and community engagement.

Table 3. Policy and governance mechanisms for circular municipal solid waste management

Governance mechanism	Principal actors	Main function	Contribution to circular MSW management	Sources
Extended Producer Responsibility	Producers, regulators and recyclers	Assigns post-consumer collection and recovery obligations to producers	Improves product take-back and material recovery	Maitre-Ekern (2021); Tong et al. (2024)
Pre-market producer	Manufacturers and product designers	Integrates durability, repairability and	Prevents waste and improves product	Maitre-Ekern (2021)

responsibility		recyclability before market entry	circularity	
Collaborative governance	Municipalities, businesses and civil society	Coordinates policy design, implementation and oversight	Reduces institutional fragmentation and strengthens accountability	Temitope (2023)
Multi-stakeholder partnerships	Government, industry, academia and communities	Combines expertise, finance and shared responsibilities	Supports innovation, knowledge exchange and collective action	Momen (2021); Eweje et al. (2021)
Context-specific policy adaptation	National and local authorities	Aligns policy instruments with regional capacity and development conditions	Improves feasibility and effectiveness across different regions	Adeniyi and Dhakar (2021); Ngoma et al. (2024)

7. Current Challenges and Research Gaps

Although there is an increasing trend of implementing circular economy (CE) principles in municipal solid waste (MSW) management, there are many challenges to the wide implementation of these principles. These issues are not just technical and include governance, funding, stakeholder coordination, infrastructure, and public involvement. These interrelated issues need to be tackled to create resilient and sustainable circular waste management systems.

One of the key obstacles is the lack of an integrated governance structure, typical of waste management in many municipalities. In many cases, there is a division of responsibilities among several agencies that have little institutional coordination, leading to inconsistencies in regulations, overlapping responsibilities and poor use of resources. Public–private partnerships (PPPs) have proven to be a successful model for providing infrastructure development and services by bringing together the public sector oversight and private sector experience and capital. However, for them to be effective, there should be clear governance, stakeholder roles and responsibilities, risk-sharing mechanisms, and an institutional will to sustain the project long-term (Selim & ElGohary, 2020).

Lack of infrastructure and budgetary limitations are also a barrier to make the shift to circular waste management, especially in less developed economies. Implementing ambientation recycling facilities, resource recovery technologies and digital systems for monitoring requires heavy capital investment, which many municipalities have a difficulty in getting access to. Moreover, the volatility of secondary raw material markets and the uncertainty of economic returns deters private investments and hinder the growth of circular business models and innovation in waste management.

Stakeholder engagement and collaborative governance are also a challenge. New policies and strategies for the transition to circular economy need to be coordinated between governments, private sector, research institutes, civil society organisations, informal waste workers and local communities. Multi-stakeholder partnerships have proven to hold much promise to mobilize expertise, finance and innovation, yet implementation of these partnerships over the long-term is challenging due to a variety of institutional priorities, governance and accountability structures. The key elements of effective partnerships are thus clear objectives, shared responsibilities, open communication, and stakeholder engagement, which are necessary to ensure a collective action towards the Circular Economy objectives (Eweje et al., 2021; Glass et al., 2023).

The effectiveness of the circular management of municipal solid waste also depends on behavioural aspects. Despite some progress, in many cities residents segregate waste and recycle and act in an environmentally responsible manner in an inconsistent way because of weak environmental awareness, low levels of motivation and poor access to supporting infrastructure. The more communities are engaged, the more they feel a part of the decision-making process, and the more they feel they are involved in governance and the community, the more likely they are to trust and commit to circular practices. Collaborative community projects have shown that continued engagement of the various stakeholders can strengthen institutions and facilitate better implementation of sustainability programmes (Ngoma et al., 2024).

There are also some areas of research that have yet to be filled. There is a lack of studies on integrated circular waste systems, with many focusing on a particular technology or single policy instrument. There is little or no information about the performance of collaborative governance models, effectiveness of partnerships, or concrete results of the cooperation between the stakeholders in municipal waste management over the long term. Future research is therefore needed to build up standardized evaluation systems which include technological, environmental, economic and social aspects of the implementation of circular economy at an institutional and partnership level, while also measuring partnership synergy. Such thorough assessments could enhance the evidence-based policy-making and enhance the scalability of circular municipal solid waste management strategies (Loban et al., 2021). Figure 3 provides an overview of the key obstacles to the circular implementation of MSW management, including governance, infrastructure, financial, technical, stakeholder and behavioural barriers.

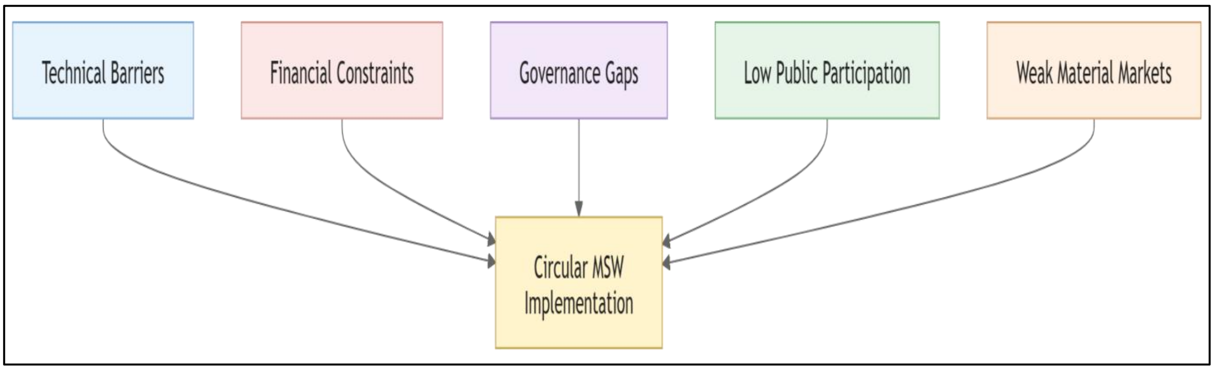

Figure 3. Major barriers to circular municipal solid waste management

8. Future Perspectives and Strategic Recommendations

Digital transformation, sustainable business innovation and integrated governance will become key aspects of future circular municipal solid waste (MSW) management. In the rapidly changing landscape of smart urban ecosystems, waste management is shifting beyond traditional collection and disposal, to the adoption of intelligent resource management systems that can help achieve environmental sustainability, economic resilience and social wellbeing. By leveraging real-time data, digital technologies, and principles of the circular economy, decision-making frameworks will help municipalities make smarter choices to optimize resource use, increase operational efficiency, and reach long-term sustainability goals. The business models of smart cities are likely to be central, offering a way to integrate technological innovation, environmental and economic performance and to evidence-based policy implementation (Krúpová et al., 2025). Further advances will also require to speed up eco-innovations along the whole waste value chain. The development of new product concepts, materials, recycling technologies and resource recovery procedures minimizes environmental effects and prolongs the life cycles of resources. Eco-innovation has the potential to proceed with the shift from linear production systems to circular, regenerative systems, by making their activities more sustainable and eco-friendly, all the while increasing resource efficiency (Pichlak & Szromek, 2022).

Business model innovation is another key priority to promote circular waste management. Ditching the ownership model and moving toward service-based, sharing, remanufacturing, and resource recovery models to keep material value in check and waste out of the picture is a growing trend. Systematic evidence shows that sustainable business model innovation promotes the adaptability of organisations and helps to ensure long-term circularity, through co-creating value and optimising resources (Brenner & Drdla, 2023). Moreover, more knowledge networks, regional cooperation and institutional cooperation are necessary in order to increase the use of circular economy business models. Improved intergovernmental, industrial, research, and local community cooperation can improve the diffusion of technology, drive eco-innovations and boost the regional circular economy that can sustain resilient and sustainable MSWM in the future (Triguero et al., 2025).

9. Conclusion

The shift from linear waste management model to circular economy is a fundamental paradigm change of waste management of municipal solid waste (MSW) and is more resource efficient, waste preventative, material recycling and value retaining throughout the waste management life cycle. This review proves that implementing the above-mentioned technologies, including source separation, recycling, composting, anaerobic digestion, and waste-to-energy can significantly decrease the reliance on landfill disposal and enhance environmental quality and resource efficiency. New digital solutions such as artificial intelligence, the Internet of Things, cloud computing and smart communication networks also improve operations and allow data-driven planning and optimized waste management. However, financial constraints, lack of infrastructure, poor governance, inconsistent policy application as well as low public engagement remain as obstacles to its wider rollout. The main challenges are met with the need for better regulations, extended producer responsibility, co-governance and more government, industry, research and community participation. Further development will rely on the pace of eco-innovation, circular business models and knowledge sharing networks, which will help resilient and inclusive waste management systems. The above-mentioned methods collectively offer a viable means for resource conservation, environmental protection and sustainable development of cities, as well as for the achievement of wider circular economy and sustainable development goals.

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