An Alternative Innovative Model for Financing Solid Waste Management in Local Authorities: A Literature Review

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ABSTRACT

This literature review investigates the development of an alternative innovative model for financing Solid Waste Management (SWM), which is a growing concern in Lusaka City due to inefficiencies in council operations and inadequate traditional financing mechanisms. Historically, SWM has been underfunded, with limited resources allocated compared to sectors like roads, education and water. Funding typically comes from local sources such as taxes, fees, permits and national support like the Local Government Equalization Fund (LGEF), grants and Constituency Development Funds (CDF), all of which have proven insufficient.

The objective of this review is to evaluate existing literature to guide the creation of a sustainable financing framework. Studies from Africa, Asia, Europe and the Americas were reviewed, highlighting alternative models such as public-private partnerships (PPP), adoption of new technologies, long-term low-interest loans and diversified investment strategies. The review is grounded in the PPP model for financing, the Behavioral Change Model for community engagement and Stakeholder Theory for inclusive planning.

This study's literature review employed the PRISMA framework to ensure transparency and rigor. A systematic search using keywords like "solid waste management," "sustainable financing," and "urban Zambia" was conducted via Google Scholar to source peer-reviewed articles, reports, and grey literature relevant to Lusaka's context. The review focused on English-language studies from 2020–2025 addressing innovative financing, community participation, or policy in low- and middle-income urban areas, especially in sub-Saharan Africa. Out of 186 initial sources, 40 were selected after screening for relevance and quality. The final selection highlighted key research gaps, including limited focus on informal settlements and PPP-related studies. The findings emphasize the need for multi-faceted, inclusive financing strategies. Identified gaps include limited community involvement and weak institutional capacity, pointing to the need for more adaptive, stakeholder-driven financial models in SWM.

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Introduction

Over the past fifteen years, literature on Solid Waste Management (SWM) has expanded in response to persistent inefficiencies in local government operations, particularly in cities like Lusaka. Literature has highlighted political (Sikazwe & Zulu, 2024), institutional (Kabwe & Chirwa, 2022), social (Chanda & Mumba, 2025) and economic (Phiri & Chipili, 2023) challenges as factors hindering effective SWM, with a strong emphasis on financial constraints and poor revenue collection. Much of the existing literature has focused on improving internal council operations and promoting private sector participation (Simukonda, 2020; Daka & Madimutsa, 2020). However, traditional financing methods such as central government funding, user fees and the Local Government Equalization Fund (LGEF) remain inadequate.

This review aims to explore an alternative, innovative financing model for SWM, making it both timely and essential given the increasing waste generation and limited fiscal capacity of local authorities. It examines theoretical foundations such as public-private partnerships (PPP), Behavioral Change and Stakeholder Theory and reviews empirical studies from Africa, Asia, Europe and the Americas. The objective is to identify scalable, inclusive and sustainable financial strategies for improved SWM outcomes.

Problem Statement

Despite rapid urbanization, Zambia's local authorities face persistent challenges in mobilizing adequate funds for effective SWM. Current financing models are reliant on central government funding, user fees and LGEF are outdated, inefficient and unsustainable. Literature reveals issues such as poor infrastructure, unplanned settlements, inadequate budgeting and low revenue collection, all of which hinder SWM efforts. The Lusaka Integrated Solid Waste Management Company (LISWMC) requires ZMW 70 million annually but received less than 10% of that in recent years, undermining its operational capacity and long-term strategic goals.

The failure to honor approved budgets has stalled implementation of key projects like the Solid Waste Management and Investment Plan (SWMIP) 2020–2024. Additionally, 80% of LGEF and local revenues are consumed by salaries, leaving minimal funds for service delivery. These limitations have created an urgent need for an alternative, innovative financing model to ensure sustainable, efficient and effective SWM in Lusaka.

Objective of the literature review

The objective of this literature review is to support the development of an alternative, innovative financing model for SWM in Lusaka City. It aims to explore sustainable financing strategies that address the city's current funding challenges, including those faced by the LISWMC. Specifically, the review will examine the extent to which existing financing mechanisms are inadequate, assess innovative models successfully implemented in other cities and evaluate their applicability to Lusaka. It will also explore how such models can be effectively designed and implemented to meet local SWM needs.

Additionally, the review will analyze the roles of key stakeholders and the factors influencing the adoption and long-term sustainability of these models. This will support the city's strategic goal of collecting and transporting 80% of its waste by 2030.

Significance of the literature review

This literature review is essential in informing the development of an alternative, innovative financing model for SWM in Lusaka City. Drawing on successful international practices and existing research, the review highlights the importance of stakeholder collaboration, diversified funding mechanisms and sustained political commitment.

It provides critical insights into the limitations of current financing approaches such as central government funding, user fees and the 80% allocation from the LGEF which have proven inadequate, contributing to poor waste collection, environmental degradation and recurring health issues.

The review also underscores the underfunding of SWM, which received just 0.6% of Zambia's 2023 national budget for environmental protection, despite its relevance to 12 of the 17 Sustainable Development Goals (SDGs). Overall, the literature review offers timely guidance for policymakers, local authorities and development partners seeking sustainable financing solutions for SWM in Lusaka.

Scope of the Literature covered

The scope of the literature covered in this study centers on identifying alternative innovative models for financing SWM, with a particular focus on

applications relevant to Lusaka City. The literature review explores three key areas; the current challenges and limitations of SWM financing in Lusaka, successful alternative financing models implemented in other urban settings globally and the design, implementation and sustainability of such models, including stakeholder roles. The review draws from academic research, case studies, policy documents and international best practices to establish a comparative framework. This enables the study to assess which financing models could be adapted to the Lusaka context.

Literature on PPPs, community-based financing and decentralized SWM systems is particularly emphasized. The scope deliberately excludes technical waste treatment methods and focuses instead on financial structures and governance mechanisms critical to sustainable SWM funding solutions.

Theoretical Framework

A theory is a set of interrelated concepts used to predict or explain a phenomenon (Ngulube, 2020). The application of various theoretical frameworks has helped conceptualize the literature review into an alternative innovative model for financing SWM in Lusaka. This theoretical framework draws upon three key theories: PPP model, the Behavioral Change model and Stakeholder theory. These frameworks play a crucial role in addressing different aspects of SWM such as financing, stakeholder involvement and behavior change, all of which contribute to a more sustainable and effective SWM system.

Public-Private Partnership (PPP) Model

PPPs are collaborative arrangements between the public and private sectors aimed at providing goods or services that neither sector could effectively deliver on its own (Longwe, 2019). In the context of SWM, PPPs are increasingly recognized as a key strategy to address inefficiencies in waste collection, disposal and recycling, particularly in Lusaka. The primary function of PPPs in SWM is to leverage the expertise, efficiency and financial resources of the private sector while utilizing the regulatory and governance capacity of the public sector. Combining the strengths of both sectors, PPPs can potentially enhance the quality of services provided to citizens while ensuring that SWM is financially sustainable.

A shift toward PPPs in SWM could offer a viable solution to these challenges by improving operational efficiency, financing mechanisms and service delivery (Roberts, 2024). In Lusaka, the traditional approach to SWM, often heavily reliant on public sector resources, has faced numerous challenges including inadequate infrastructure, limited financial resources and inefficient waste collection systems. These issues have led to inadequate service delivery, resulting in uncollected waste, environmental pollution, and public health concerns.

The private sector's involvement in these partnerships allows for the introduction of innovative technologies, better resource allocation and the development of efficient SWM systems that can meet the growing demand of urban populations (World Economic Forum, 2024). The PPP model supports the integration of private sector investments and expertise into public services. Several international examples demonstrate the success of this approach, particularly in urban centers that face similar challenges with SWM. PPPs have been instrumental in cities across Europe and Sub-Saharan Africa, for instance, in improving waste collection rates, waste sorting and recycling efforts.

The private sector's efficiency and expertise in operations management can lead to improved SWM services, ultimately benefitting the residents of Lusaka (Diangamo, 2020).The PPP model aligns directly with this study's exploration of an innovative model for financing mechanisms for SWM in Lusaka because it focuses on financing and resource mobilization. The private sector can bring much-needed financial investment into the SWM sector, enabling the development of infrastructure such as waste collection vehicles, recycling facilities and waste treatment plants.

Furthermore, the success of PPPs in SWM depends on effective contract management, continuous monitoring and evaluation and a long-term commitment to sustainable SWM practices (Daka & Madimutsa, 2020). Alignment in terms of goals, responsibilities and risk-sharing mechanisms is critical in both sectors for PPPs to be successful in the context

of SWM in Lusaka. This requires clear regulatory frameworks, transparent governance structures, and an equitable distribution of benefits.

The Role of Public-Private Partnerships (PPPs) in Financing Waste Management

One of the central focuses of this literature review is to assess the role of PPPs in financing and improving SWM practices in Lusaka. In the case of SWM, PPPs can bring together the expertise, technical capabilities and financial resources of the private sector with the regulatory and governance functions of the public sector. In Lusaka, a PPP approach to SWM could offer several advantages, including:

Improved Efficiency and Service Delivery

The private sector's efficiency and expertise in operations management can lead to improved SWM services ultimately benefiting the residents of Lusaka (Mwanaumo & Mambwe, 2020). PPPs can lead to the introduction of more efficient waste collection methods, improved waste segregation practices and the establishment of modern recycling and waste processing facilities. The private sector's ability to innovate and invest in infrastructure could help overcome the limitations of the current SWM system, resulting in better service delivery.

Access to Private Sector Financing

One of the most significant challenges facing SWM in Lusaka is financial constraints (Mwanaumo & Mambwe, 2020). The public sector has limited capacity to fund large-scale SWM infrastructure projects. PPPs allow for the mobilization of private sector capital, which can be used to build and maintain SWM facilities such as landfills, composting plants, recycling centers and waste-to-energy plants. Through such collaborations, Lusaka could secure the necessary financing to improve SWM infrastructure and services. Mwanaumo and Mambwe highlight the private sector's involvement in these sectors and how they bridge financing gaps and enhance service delivery. They recommend promoting PPPs to address critical infrastructure deficits, emphasizing that sharing risks and rewards is essential to attract quality private partners.

Risk Sharing

Risk-sharing mechanisms can help create long-term, sustainable financing models for SWM (Mwanaumo & Mambwe, 2020). SWM projects often involve high upfront costs and risks, such as fluctuating waste volumes and operational challenges. PPPs provide an opportunity to share these risks between the public and private sectors, reducing the financial burden on the government while encouraging private sector investment.

Transfer of Technology and Expertise

In many cases, the private sector brings advanced technologies and management expertise that can significantly improve waste collection, sorting and recycling processes. Private companies with experience in SWM for instance may introduce more effective waste processing technologies, such as automated sorting systems, waste-to-energy technologies and efficient transportation methods. This expertise can play a vital role in improving the efficiency and sustainability of SWM services in Lusaka.

The GREEN Tech4CE project was launched in July 2024 to provide technical assistance and financial support to SMEs, fostering innovation and technology transfer which can be beneficial for SWM practices.
To explore the potential for PPPs in Lusaka, the literature has revealed existing partnerships between the public and private sectors in WM, both within Zambia and internationally. Case studies from cities with successful PPP SWM projects will provide valuable insights into how such models can be adapted to the local context in Lusaka.

Behavioral Change Model

While the PPP model primarily focuses on financing and operational aspects of SWM, the Behavioral Change model addresses the fundamental need for changes in attitudes and behaviors toward SWM practices. Effective SWM not only requires proper infrastructure and financing but also the active participation and cooperation of individuals and communities. In Lusaka, as in many other urban centers, one of the major challenges in SWM is the

failure of residents to engage in responsible waste disposal practices (Kachinda, 2024). Wezi Kachinda reveals that failure of residents to engage in responsible waste disposal practices such as not practicing waste segregation, not recycling and improper disposal of hazardous materials is one of the major changes in SWM is the

The Behavioral Change model emphasizes the importance of altering individuals' attitudes and behaviors to foster more sustainable SWM practices (Nyambe & Chileshe, 2023). Waste sorting at the source, where households and businesses separate recyclables from non-recyclables for instance, is critical to improving SWM. In many urban settings, the lack of such behavior leads to contamination of recyclable materials and the inefficient disposal of waste, making it more difficult to recycle or repurpose waste products.

A behavioral change approach to SWM requires a multifaceted strategy that includes education, awareness campaigns, social norms and incentive structures to encourage individuals and communities to adopt pro-environmental behaviors (Ailyn, 2023). In Lusaka, a significant portion of the population may not fully understand the benefits of waste segregation, recycling or reducing waste generation. Therefore, changing these behaviors is essential to the success of any new SWM system.

The model emphasizes that, for behavior change to occur, individuals must be aware of the problem, understand the consequences of their actions, and feel motivated to act (Zhao & Zhang, 2024). Theories of behavior change, such as the Theory of Planned Behavior and Social Cognitive Theory, suggest that people are more likely to change their behavior if they perceive that they have control over their actions (i.e., they could sort waste) and if they believe that others in their community are also participating in similar practices.

The involvement of stakeholders in SWM, particularly in educating and motivating residents, can foster a cultural shift toward more sustainable behaviors (Abila, 2018). Incentive programs, such as offering discounts on waste collection fees for households that segregate waste, or penalties for improper waste disposal, can also be effective tools for encouraging compliance with SWM policies. In the context of Lusaka, this literature reveals how behavioral change interventions, such as education campaigns and community engagement strategies can complement the PPP model in improving the effectiveness of SWM services.

Encouraging residents to actively participate in waste sorting, recycling and paying for services is integral to the sustainability of SWM initiatives. Furthermore, successful behavior change can reduce the burden on waste collection services and create a more sustainable SWM system in Lusaka.

Impact of Behavioral Change on Waste Management Practices

Another critical aspect of the literature review is the impact of behavioral changes on waste generation, sorting, recycling and public engagement in SWM systems. The Behavioral Change model posits that effective SWM is not solely reliant on infrastructure and financing but also on changes in the behaviors of individuals and communities. In Lusaka, where waste sorting and recycling practices are not widespread, fostering a culture of responsibility among residents is essential to improving SWM outcomes.

The literature review examines the following aspects of behavioral change:

Waste Sorting and Recycling

The implementation of waste sorting at the household and community levels is critical for improving recycling rates and reducing the amount of waste sent to landfills (Mbuzi, 2023). In Lusaka, the lack of awareness and incentives for sorting waste at the source has contributed to poor recycling rates. The literature review explore how education campaigns, social norms and incentives can motivate residents to adopt waste segregation and recycling practices. Mbuzi proposed strategies such as developing comprehensive SWM plans encouraging waste segregation, investing in recycling facilities and enforcing regulations.

Public Awareness and Education

Raising awareness about the environmental and economic benefits of recycling and waste reduction is crucial for changing public attitudes toward SWM. The literature review assesses the effectiveness of awareness campaigns in Lusaka, including government-led initiatives, non-governmental organization (NGO) programs and private sector-driven efforts. In September 2024, the Ministry of Local Government and Rural Development (MLGRD) launched the **Keep Zambia Clean, Green and Healthy Communication Strategy** (2024-2028) to promote environmental cleanliness and health. The strategy includes public awareness campaigns and educational programs to encourage proper waste disposal.

Incentive Programs

Incentive programs, such as offering discounts on waste collection fees for households that separate recyclables from non-recyclables, have proven successful in other cities (Abila, 2018). The literature review explores whether similar incentive schemes could be implemented in Lusaka to encourage residents to participate in SWM programs actively.

Community Engagement

Public engagement is essential for ensuring that residents take ownership of SWM practices (Nyambe & Chileshe, 2023).Community-driven initiatives, such as waste collection and recycling projects, have the potential to enhance participation and promote a sense of shared responsibility for the environment. The literature review investigates how community engagement strategies can be employed to increase public participation in SWM.

Stakeholder Theory

Stakeholder Theory provides a comprehensive framework for understanding how various actors, both within and outside the formal PPP, influence and are influenced by SWM decisions. In the context of SWM in Lusaka, the involvement of a broad range of stakeholders, including residents, government agencies, private sector firms, non-governmental organizations and international donors, is essential for achieving sustainable outcomes.

Stakeholder theory emphasizes the importance of considering the interests, needs and expectations of all relevant stakeholders when designing and implementing policies or services (Mwanaumo *et al*, 2024). In Lusaka, the successful implementation of an alternative Innovative model for financing SWM will require coordinated participation from all these stakeholders, each of whom has a vested interest in the outcome. Erastus Mwanaumo, Kachikoti Banda and Bupe Mwanza emphasize the important roles various stakeholders play in SWM in Lusaka city.

The government's role is to regulate and enforce policies, while the private sector's role is to provide technical expertise and financial and finally residents must actively engage in waste sorting, recycling and paying for services to ensure that SWM services are effective. A key tenet of Stakeholder Theory is the notion of stakeholder salience, which refers to the relative importance of different stakeholders in the decision-making process. In the case of Lusaka's SWM system, the government and private sector may have greater decision-making power, but the active engagement and cooperation of residents are equally important for the success of SWM initiatives.

A lack of public cooperation can undermine the effectiveness of any SWM strategy, regardless of the financial or technical resources available (Daka & Madimutsa, 2020) . Daka and Madimutsa emphasize how decisions are primarily made by government officials and private companies with residents being informed during meetings.

Stakeholder theory also suggests that the power dynamics among different stakeholders can influence the success of a project. Engaging residents in decision-making processes, through public consultations or community-based approaches, can help ensure that SWM initiatives are aligned with local needs and preferences (Shikabi, 2019). The government, for example, may have the regulatory power to mandate certain SWM practices, while private companies may have the financial resources to invest in waste collection infrastructure. However, the role of residents, as primary participants in waste sorting and recycling, should not be underestimated.

In the context of Lusaka, Stakeholder Theory supports the idea that a collaborative approach to SWM, involving all relevant stakeholders, is critical for the adoption of alternative innovative model for financing SWM. The literature review aims to investigate how the dynamics between government, private sector and local communities shape the potential for successful partnerships and financing models for SWM in Lusaka.

Stakeholder Collaboration and Shared Responsibility

Effective SWM systems rely on the active participation and collaboration of various stakeholders, including government agencies, private sector companies, non-governmental organizations and local communities. Stakeholder Theory emphasizes the importance of considering the interests, concerns and capabilities of all relevant parties when designing and implementing SWM policies (Valentinov, 2023)

In Lusaka, the role of stakeholders is critical in improving SWM practices. Government agencies are responsible for regulating SWM policies, enforcing regulations and ensuring that public services are provided.

Private sector companies, including SWM service providers, bring technical expertise, investment and innovation to the system. NGOs can play a role in raising awareness, promoting public participation and supporting local communities. Finally, residents themselves must take responsibility for properly sorting and disposing of their waste (Ogunbayo & Adeyemo, 2019). Ogunbayo and Adeyemo discussed in detail the collaboration between government and private entities in enhancing SWM efficiency.

The literature review examines how the collaboration and coordination of these stakeholders can contribute to more efficient and sustainable SWM practices in Lusaka. It aims to understand how to create a more integrated SWM system where all stakeholders work together to address common challenges and achieve sustainable outcomes.

Methodology

The literature review informing this study was systematically conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency, replicability, and methodological rigor. The search strategy included combinations of keywords such as *"solid waste management," "sustainable financing," "public-private partnerships," "community engagement," "digital payment,"* and *"urban Zambia."* Searches were conducted across multidisciplinary sources using Google Scholar to capture peer-reviewed journal articles, institutional reports, and grey literature relevant to Lusaka's SWM context.

Inclusion criteria comprised literature published between 2020 and 2025, in English and studies focusing on low- and middle-income urban settings, particularly in sub-Saharan Africa. Empirical and theoretical studies were considered if they addressed innovative or alternative financing models, community participation, or policy frameworks in SWM. Exclusion criteria eliminated sources focusing solely on rural waste management, highly technical engineering solutions without financial or policy linkage, or studies outside of the urban African context.

The selection process began with an initial yield of 186 sources. After removing duplicates and screening titles and abstracts for relevance, 72 full-text documents were reviewed. A final 40 sources were included based on their methodological quality, relevance to the Zambian or similar urban African contexts, and their alignment with identified research gaps. This process helped to clearly identify literature gaps including limited attention to informal settlements, insufficient analysis of community financing willingness and a lack of empirical studies on PPPs in SWM which this study directly addresses through its mixed-method case study design (Sikalumbi, 2023).

Literature Review and Synthesis

This section synthesizes global and regional literature on alternative innovative models for financing SWM. The review is organized thematically and regionally, with a focus on PPPs, community involvement, technological innovation and economic instruments. The review draws on journal articles, case studies,

government and NGO reports from Africa, Asia, Europe, and the Americas.

Public-Private Partnerships (PPPs) and Community Engagement

PPPs emerge as a dominant financing model across regions. LCC initiated PPPs in 2003 to improve efficiency in urban SWM (Chisenga & Simbeye, 2024). Studies from Kenya, Ghana and Tanzania confirm similar trends, highlighting the expertise and resource availability of private firms (Amugsi & Muindi, 2022; Toku & Mabe, 2024; Adedara & Taiwo, 2023). However, some challenges persist, such as lack of transparency and limited public accountability (Kihila & Wernsted, 2021). Community participation is often emphasized as a success factor but remains inconsistently implemented.

In Asia, PPPs show mixed results. While India has seen expanded service coverage, service quality and sustainability vary (Ngullie & Maturi, 2021; Sandu, 2020). In Thailand and the Philippines, localized governance and multi-stakeholder collaboration have proven more effective (Wiangnon, 2023; PPP, 2025). Table 1 below is a comparative analysis of PPP implementation strength and weaknesses in Africa and Asia.

Table 1 Comparative Analysis of PPP Implementation in SWM (Africa vs. Asia)

Country	PPP Strength	PPP Weakness	Community Role
Zambia	Improved collection via LCC	Weak oversight, informal areas left	Emerging
India	Expanded Coverage	Inconsistent quality	Minimal
Philippines	Strong private engagement	Institutional fragmentation	Localized and growing

Technological Innovation in Financing and Operations

Across all continents, technological tools are transforming SWM financing and delivery. IoT-integrated smart bins and AI-driven sorting systems are improving operational efficiency (Spyrids & Argyriou, 2024; Ghahramani et al., 2022). Israel and Colombia have adopted technology-based financing models like landfill levies and tax exemptions for recycling (Cohen, 2024; Chioatto & Sospiro, 2023). South Korea offers long-term low-interest loans for SWM infrastructure (Park, 2019), and Japan provides direct capital subsidies.

The main strength of tech-based financing is its scalability and transparency. However, a common weakness is limited adoption in low-income regions due to capital costs and lack of institutional capacity. Table 2 below illustrates the use the technology by country, technology used, financing mechanisms and challenges faced.

Table 2: Use of Technology in SWM Financing Across Regions

Country	Technology Used	Financing Mechanism	Challenges
Europe	IoT, AI, Tax incentives	Landfill levies, recycling credits	High capital investment
Asia	Smart bins, subsidies	Government loans and incentives	Unequal access, urban bias
Africa	Limited	Experimental PPPs	Infrastructure and funding gaps

Economic Instruments and Blended Finance

Economic instruments such as user fees, landfill taxes and international aid are widely used but unevenly effective. Bristow & Ezeudu (2024) argue that when user fees are transparently implemented alongside PPPs, they ensure financial sustainability. However, Bharadwaj et al. (2020) caution against over-reliance on subsidies, citing economic volatility and limited revenue generation.

Blended finance and international cooperation models, like the AIIB's support in Indonesia and Canada's Equality Fund, bring global capital to local contexts (Wilcox, 2020; AIIB, 2024). These require strong institutional coordination and policy frameworks, which are often weak in developing countries.

Critical Synthesis and Research Gaps

While the reviewed studies collectively highlight a range of innovative financing models, several gaps and limitations are evident:

- **Strengths:** Diverse models (PPPs, tech, loans) show promise when well-integrated with policy and stakeholder engagement.
- **Weaknesses:** Many studies lack empirical depth, especially in community-centered or informal settlement-focused financing models.
- **Contributions:** Literature from Asia and Latin America provides strong examples of blended finance, while African studies emphasize institutional reform needs.

Key Research Gaps Identified:

- Limited empirical research on community willingness to pay and use of digital payment systems in African cities.
- Lack of case-based analysis on adaptive, localized financing models in informal settlements.
- Insufficient comparative work evaluating long-term impacts of PPP and technology-based financing on service sustainability.

Discussion

The integration of Fourth Industrial Revolution (4IR) technologies into SWM financing presents transformative opportunities and also introduces complex challenges. This synthesis critically evaluates the implications of current findings, highlighting areas of consensus and divergence and situates these insights within the broader context of 4IR.

Implications of Findings

The literature underscores a growing consensus on the necessity for innovative financing models in SWM. Technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) and blockchain are increasingly recognized for their potential to enhance efficiency and transparency in waste management systems. IoT-enabled smart bins, for instance, can optimize collection routes, while AI algorithms can predict waste generation patterns, leading to more efficient resource allocation. Additionally, blockchain technology facilitates traceability in recycling processes, ensuring accountability and encouraging participation.

However, the implementation of these technologies is not without challenges. The high initial costs associated with 4IR technologies can be prohibitive, particularly for municipalities in low and middle-income countries. Moreover, there is a need for capacity building to ensure that local authorities can effectively manage and maintain these advanced systems. These barriers highlight the importance of inclusive financing strategies that consider the economic constraints of different regions.

Areas of Consensus and Divergence

There is a shared understanding among researchers that a multi-faceted approach to SWM financing is essential. This includes PPPs, user fees and innovative financial instruments. The "Pay As You Throw" (PAYT) model, for example which charges users based on the amount of waste they generate, has been identified as an effective mechanism to promote waste reduction and ensure equitable cost distribution.

Divergence arises in the application and scalability of these models. While PAYT systems have been successful in certain contexts, their applicability in regions with informal waste sectors or low-income communities is limited. This necessitates the development of context-specific financing models that are adaptable to local socio-economic conditions.

Relation to the Fourth Industrial Revolution

The 4IR is characterized by the fusion of advances in artificial intelligence, robotics, the Internet of Things, genetic engineering, quantum computing, and other technologies. In the context of SWM, these technologies can facilitate the transition from traditional linear waste management systems to circular economies. For instance, AI and IoT can enable real-time monitoring and optimization of waste collection, while blockchain can enhance transparency and trust in recycling processes in Lusaka city.

However, the adoption of 4IR technologies in SWM financing requires careful consideration of ethical, social and economic implications. There is a risk that the benefits of these technologies may not be equitably distributed, potentially exacerbating existing inequalities. Therefore, it is crucial to ensure that the implementation of 4IR technologies in SWM in Lusaka city is accompanied by policies that promote inclusivity and equity.

The integration of 4IR technologies into SWM financing offers significant potential to enhance efficiency and sustainability. However, realizing this potential requires addressing challenges related to cost, capacity, and inclusivity. Future research should focus on developing adaptable, context-specific financing models that leverage 4IR technologies while ensuring equitable access and participation. Aligning technological advancements with inclusive financing strategies, LCC can create resilient and sustainable waste management systems that contribute to the broader goals of the circular economy and sustainable development.

Research Gaps and Future Directions

Current literature highlights several gaps in the financing of SWM, particularly in low- and middle-income contexts. First, there is limited empirical research on community willingness to pay and the use of digital payment systems in informal and peri-urban areas. Second, while PPPs are widely discussed, few studies evaluate their long-term sustainability and performance metrics, especially in Sub-Saharan Africa.

Additionally, despite recognition of 4IR technologies like IoT and AI in improving SWM, research is lacking on how to adapt and scale these technologies in low-resource settings. There is also insufficient analysis of blended financing models, such as those involving international donors, green bonds or climate funds and their role in enhancing financial sustainability in waste services.

Future research should focus on:

- Designing locally adaptable financing models that integrate community participation and digital tools.
- Evaluating the institutional readiness and capacity needs for implementing 4IR technologies in SWM.
- Investigating the impacts of circular economy frameworks on financing models.
- Conducting comparative case studies on successful PPPs and blended financing strategies.
- Exploring the role of behavioral economics and incentives in improving household and business participation in waste services.

These directions would provide actionable insights for policymakers and practitioners seeking inclusive, scalable and future-ready solutions for sustainable SWM financing.

Conclusion

This review has examined a wide range of alternative and innovative models for financing SWM across global contexts, with particular attention to PPPs, community participation, technological integration and economic instruments. The findings underscore the growing consensus that traditional reliance on government subsidies and user fees is insufficient to sustain efficient, inclusive, and environmentally responsible SWM systems.

Key takeaways include the demonstrated success of PPPs in improving service delivery when implemented transparently and collaboratively and the transformative potential of 4IR technologies such as IoT, AI and blockchain in enhancing operational

efficiency and financial accountability. However, adoption remains uneven, particularly in low-income contexts where institutional capacity and funding constraints limit implementation. Furthermore, community engagement and localized governance models are crucial but remain underexplored in both policy and academic literature.

The significance of these findings lies in their contribution to reshaping the discourse on SWM financing from a narrow, government-centric view to a more diversified, adaptive and stakeholder-driven framework. This review provides a comparative perspective that can inform future innovations and policy reforms with synthesizing evidence from Africa, Asia, Europe and the Americas.

Overall, this article contributes to both academic knowledge and practical application by identifying effective models, highlighting persistent gaps, and outlining a clear agenda for future research and investment. It calls for the integration of inclusive financial strategies, institutional reform and technological adaptation to build sustainable SWM systems aligned with circular economy goals and 4IR opportunities.

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