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ARTICLE

Efficient Solid Waste Management at Ha Tsosane Maseru, Lesotho

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ABSTRACT

Solid waste management has become a growing concern in many urban areas due to rapid population growth, urbanization and increased global relevance and why the study matters. This study examined how solid waste is managed, collected and transported in Maseru City, with the aim of identifying ways to improve service delivery while reducing environmental impacts makes the purpose more precise and concise. Data were collected using a combination of questionnaires, interviews and direct observation, providing reliable first-hand information on existing practices and challenges, avoiding unnecessary detail and improving clarity. The findings reveal that waste management in Maseru is constrained by poor planning, including the unsuitable location of the Ts'osane dump site, the absence of designated collection points and a lack of organized collection routes shifts from description to interpretation of results. Waste collection areas are mainly determined by population size and waste generation levels rather than systematic planning, while access limitations further affect service coverage. These challenges reduce the efficiency of waste services and contribute to environmental risks links findings to their implications. The study concludes that improving waste management in Maseru requires better planning and the development of clear, science-based guidelines for selecting disposal sites and organizing collection systems. Strengthening these aspects would enhance service efficiency, reduce environmental impacts and support sustainable urban development states recommendations and practical significance.

Keywords: Sanitation; Waste Collection and Transport; Maseru City; Urban Waste; Disposal Site Selection and Waste Policy

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1. Introduction

Managing solid waste is a growing global problem. This is mainly caused by rapid population growth, increased consumption, and fast urban development. As cities expand, the amount of municipal waste increases faster than the population. This shows that urban systems are under pressure to handle rising waste volumes [1], which explains the implications of the study. This trend is linked to higher incomes, changes in lifestyle, and the increased use of packaged products. Large cities around the world now produce very high amounts of waste each year. This highlights the growing scale and complexity of waste management systems [2], linking evidence to broader issues. In developed countries, people living in cities produce between 1.5 and 2.5 kg of waste per person per day. This results in millions of tonnes of waste each year in large cities [3]. In developing countries, waste generation is lower, usually between 0.3 and 0.7 kg per person per day [4]. However, waste volumes in these countries are increasing quickly due to urbanization [5]. This suggests that developing cities may face similar or even greater waste management challenges in the future adds forward looking analysis.

Wealthy countries generally spend more on waste services through taxes and service fees [6]. In contrast, developing countries spend much less, which makes it difficult to manage waste effectively [7]. In poorer cities, waste management can take up a large part of municipal budgets. This leaves limited resources for equipment, infrastructure, and skilled workers [8]. As a result, a cycle is created where limited funding leads to poor infrastructure, which then causes inefficient waste collection and more environmental problems connecting key concepts: funding → infrastructure → efficiency → environment. Regular and efficient waste collection and disposal are very important for protecting human health and the environment. When waste is not collected on time, people often dump it illegally or use unsafe disposal methods. These problems are usually caused by poor planning, limited funding, weak law enforcement, and a shortage of vehicles [9]. As a result, pollution increases, diseases can spread, and drainage systems may become blocked. This clearly shows the link between poor waste management and public health risks [10] strengthened analytic linkage. While these challenges are widely documented at the global level, there is limited empirical evidence on how they specifically affect waste management systems in Maseru City. In particular, there is a lack of detailed understanding of how waste is collected, transported, and managed, and how existing challenges influence service delivery and environmental outcomes add research gap and is narrowed to local context. Maseru City, like many urban areas in developing countries, is experiencing rapid urban growth, which places increasing pressure on its waste management systems. However, constraints such as limited funding, poor infrastructure, and weak planning continue to affect the efficiency and coverage of waste services introduced study area and localized problems.

This study aims to assess solid waste management practices, challenges, and their impacts on the environment and public health in Maseru City. It also seeks to identify possible strategies for improving waste management systems. The specific objectives are to examine existing waste collection and transportation practices, identify key operational and institutional challenges, and evaluate their implications for environmental sustainability and public health expands aim into clear objectives.

2. Literature Review

Solid waste management has several stages. These include waste generation, temporary storage, collection, transport, treatment and final disposal. Among these stages, collection and disposal are usually the most expensive and difficult. This is especially true in low-income urban areas. In many developing regions, waste services do not reach all neighborhoods and disposal methods are poorly managed [11]. Because of this, open dumping and unsafe landfill practices are common.

Studies in African cities show that waste systems are often inefficient. This is due to limited funding, poor road conditions, a lack of vehicles and equipment, weak institutions and a shortage of trained workers [12]. When local authorities do not provide regular services, many residents dispose of waste in unsafe ways. They may throw waste in open spaces, burn it or dump it in rivers and drainage channels. These actions cause se-

rious problems such as pollution, health risks, flooding and the release of harmful gases like methane [13].

Different waste collection methods include house-to-house collection, shared collection points, roadside pickup and transfer stations [14]. Door-to-door collection is convenient, but it is expensive and not suitable for overcrowded or poorly planned cities. Studies show that shared collection points and organized routes are often cheaper and more efficient, especially when communities are involved [15].

Open dumping is still widely used in developing countries because it is cheap and easy [16]. However, it causes serious environmental and health problems, including air and water pollution, bad smells and disease outbreaks [17]. For this reason, waste disposal sites should be properly planned and managed using environmental and scientific standards. There is also a need for integrated waste systems that connect collection, transport and safe disposal [18].

Choosing the right location for a waste disposal site is very important. A poorly chosen site can lead to environmental damage, social conflict, health risks and high transport costs [19]. Research shows that disposal sites should be selected using scientific methods and clear criteria, rather than convenience or political reasons [20]. One common method is GIS-based suitability analysis. This method looks at environmental and human factors to find safe locations for waste facilities while reducing negative impacts.

Important factors include distance from homes and water sources, land use, soil type, slope, geology, road access and proximity to protected areas. Waste sites should be located far from residential areas and water bodies to reduce pollution risks and community complaints [21]. Waste collection and transport depend on good route planning and proper placement of collection points. Studies show that these activities can account for more than half of total waste management costs [22]. Good planning helps reduce costs, save time and improve service delivery.

Network analysis is a GIS tool used to design efficient routes for waste collection vehicles. It helps reduce travel distance, time and fuel use [23]. This method replaces unplanned house-to-house collection with organized routes and schedules. Software such as ArcGIS can be used to test different route options and find the most efficient ones. Location-allocation analysis is another GIS method. It is used to decide where to place waste collection points or transfer stations. Instead of trucks visiting every home, residents take their waste to nearby collection points. This reduces travel distance and improves efficiency. The method considers factors such as population size, road access and reasonable walking distances. Modern studies combine suitability analysis, network analysis and location-allocation methods. Together, these approaches reduce costs and travel time, protect the environment and improve waste management systems [24].

3. Methodology

3.1. Area of Study

The research was conducted in Maseru, the capital and largest urban center of Lesotho. The city is located in the western lowlands, near the border with South Africa. Maseru lies at approximately 29.31° S latitude and 27.48° E longitude. It covers an area of about 138 km^2 and has a population of more than 300,000 people. The city is bounded by the Mohokare River to the west and is surrounded by peri-urban and rural settlements. Its urban structure includes a mix of formal residential areas, informal settlements, commercial zones and industrial areas geographic location, coordinates, boundaries, population size and urban structure.

The study focused on how waste is managed, collected and transported. The aim was to improve service delivery and reduce environmental harm. Most of the waste in Maseru is taken to a single dumping site in Ha Ts'osane village, about five kilometers from the city center. This site is located close to residential areas. Polluted liquid from the waste, known as leachate, sometimes flows into nearby homes. This causes contamination, bad smells and possible health risks [25] improved wording: clearer and more formal description of impacts. Maseru was selected because waste management is a major challenge in Lesotho, as in many developing countries. Rapid population growth, increasing waste generation and weak planning systems have made

it difficult to manage waste properly [26]. The city is also suitable for studying modern waste management solutions. This is due to its growing population, increasing waste volumes and the need for better planning and use of technology. However, there are several infrastructure gaps. These include the lack of real-time monitoring systems, inefficient waste collection routes and limited use of data for planning justification of the study and infrastructure gaps and smart waste relevance. These challenges reduce the effectiveness of waste services.

The city is divided into ten constituencies: Abia, Khubetsoana, Lithabaneng, Thetsane, Lithoteng, Mabote, Maseru, Motimposo, Qoaling and the Stadium area. Each constituency contains several villages and wards. This makes Maseru suitable for studying waste management across different communities. Waste collection is carried out by the Maseru City Council, together with community-based organizations and informal waste collectors. Although the council is mainly responsible, it faces several challenges. These include limited funding, poor road conditions, lack of equipment and shortages of staff. The waste produced in the city includes different types of solid waste. These include household waste, organic waste, plastics, paper and other non-biodegradable materials. Poor handling and disposal of waste create serious environmental risks. These include groundwater contamination from leachate, air pollution from open burning and the spread of disease-carrying organisms such as rodents and insect types of waste and environmental risks such as groundwater, air pollution and disease vectors. Community groups and informal collectors also help with waste management, but their services are not always consistent. As a result, some residents still burn or dump waste illegally. These practices harm both the environment and public health. This shows the need for a more organized and effective waste management system in Maseru.

3.2. Research Approach

The study used a mixed research approach called a convergent parallel mixed-methods design type of mixed methods. This approach combines numerical data and descriptive information to examine the current state of waste management in Maseru. It was suitable because waste management involves technical, environmental, social and institutional factors [27]. Mixed methods allow for a more complete analysis. Quantitative data, such as waste volumes, service coverage and operational efficiency, provide measurable results. Qualitative data, such as stakeholder experiences, perceptions and challenges, help explain these results in more detail why mixed methods are used and what each method contributes.

The quantitative and qualitative data were collected and analyzed separately. They were then combined during the interpretation stage. This process helped to compare, confirm and complement the findings from both methods. As a result, the study provides a clearer and more complete understanding of waste management practices and challenges in the study area how data are integrated. This approach supports the study objectives. Quantitative data help examine existing waste collection and transport systems, while qualitative data identify operational and institutional challenges. When combined, the findings also help assess the effects of waste management on environmental sustainability and public health, linking to research objectives and methodological justification.

3.3. Population of the Study

The study population included all people and groups involved in waste generation, collection, transportation and disposal in Maseru City. This included households from all constituencies, Maseru City Council (MCC) officials and drivers, community-based organizations, volunteer waste collectors and truck owners who transport waste to the Ts'osane dump site. These stakeholders play an important role in the city's waste management system and provide different views on how it works. This selection follows the principles of the Integrated Sustainable Waste Management (ISWM) framework, which highlights the importance of involving many stakeholders in the waste management system, including service users, service providers and government institutions links stakeholders to the ISWM framework.

The total study population was estimated to include more than 1,100 residents in Maseru City, together

with both formal and informal actors involved in waste management activities population size was added. This wide coverage supports a system-based analysis by capturing how different parts of the waste management system interact. It includes social, institutional and operational aspects of the system connects population to system-based analysis. A mixed sampling approach was used, combining probability and non-probability sampling methods. Households were selected using simple random sampling. Purposive and convenience sampling were used to select MCC officials, drivers, community-based organizations, informal waste collectors and truck owners because of their availability and relevance to the study sampling methods clearly identified. This approach is consistent with the ISWM framework because it ensures that both formal and informal actors are represented. These actors are important for understanding how the waste system works in real life links sampling to ISWM inclusiveness. The sampling frame included households from all constituencies of Maseru, MCC management staff and drivers, registered and informal community-based organizations, volunteer waste collectors working in the city and truck and van owners who transport waste to the Ts'osane dump site sampling was framework defined.

These groups represent key stages of the waste management process, from waste generation to final disposal. This allows for a complete system-level assessment connects sampling frame to waste system stages. The study included 120 informal waste collectors, 15 MCC management staff and 5 waste truck drivers. In addition, 64 house-to-house waste collectors and 9 truck and van owners were interviewed to provide practical insights into waste collection and transportation sample sizes stated clearly.

The use of both quantitative and qualitative data from these groups supports a detailed analysis of technical performance, stakeholder roles and institutional challenges within the ISWM framework links sample to analytical depth in ISWM. Households were randomly selected across constituencies to ensure fair representation and reduce bias. Informal waste collectors and community-based organizations were selected through convenience sampling because they were easy to access in active waste collection areas. MCC officials and drivers were purposively selected because they are directly involved in decision-making and daily operations. Truck and van owners were also purposively selected as key participants in transporting waste to the Ts'osane dump site how each group was selected. These selection methods help the study to examine both system performance, such as efficiency and service coverage and governance issues, such as planning and coordination.

3.4. Data Collection Methods

Households were selected using simple random sampling. This means that each household in the sampling frame had an equal and known chance of being chosen. This method helped to reduce selection bias and improve the reliability of the results. The sampling frame included households from all ten constituencies of Maseru City. A total of 13 households were selected from each constituency, giving a total sample of 130 households clarified sampling method and sampling frame and total household sample size and number of constituencies. Data were collected through face-to-face interviews using a structured questionnaire. This ensured that all participants answered the same questions. The questionnaire had key sections on waste generation, waste storage practices and waste collection and disposal methods. This helped to collect complete information on household waste management. A pilot study was conducted before the main survey to test the clarity and reliability of the questionnaire and to make necessary improvements add questionnaire structure and pilot study.

Convenience sampling was used to select community waste collectors, community-based organizations (CBOs) and transport operators because they were easy to access. In total, 64 house-to-house waste collectors and 9 truck and van owners were interviewed. Maseru City Council (MCC) officials and drivers were also included in the study. Since MCC had only three waste drivers, all of them were interviewed. Because community waste collectors were not formally organized, the researcher worked with community chiefs to identify active waste collection groups. Overall, the total sample size included 130 households, 64 waste collectors, 9 transporters and 3 MCC drivers. This ensured repre-

sentation of both service users and service providers. Data collection was carried out over a defined period, between June and August 2025. This allowed enough time to collect consistent and reliable data from all groups total sample clarity and timeframe added.

3.5. Ethical Considerations

Before collecting data, the researcher asked for permission from village or ward chiefs. The approval process differed depending on local leadership practices. The study followed standard research ethics principles. These included voluntary participation, informed consent, confidentiality and ensuring that no harm was caused to participants add ethical framework and core principles. The researcher explained the purpose of the study to all participants before data collection began. Participants were informed about the objectives of the study, their right to refuse participation and their right to withdraw at any time without any negative consequences. Verbal informed consent was obtained from all participants before the study started expand consent details and voluntary participants.

Anonymity was maintained by not recording participants' names or any personal identifying information in the questionnaires or interview records. Instead, codes and general descriptions were used to represent participants explain anonymity. Confidentiality was ensured by limiting access to the collected data to the researcher only. All information provided by participants was treated as confidential and used only for academic purposes clarified confidentiality measures.

Data protection procedures were also followed. All collected data will be stored securely in password-protected digital files and, where necessary, in locked physical storage. The data will be kept only for the time needed to complete the study and will then be safely disposed of to prevent unauthorized access explain data storage and protection.

3.6. Data Validation and Transparency

The researcher compared information from questionnaires, interviews and field observations using data triangulation. This means that findings from different sources were carefully checked against each other to identify similarities and differences specify validation strategy**:** triangulation instead of general statement. Field visits were also carried out to confirm that the mapped information matched actual site conditions. This included checking waste collection points, disposal practices and transport routes observed during the study replace vague phrasing with specific verification actions. For quantitative data, validation involved checking for missing values, identifying unusual results (outliers) and confirming that responses were consistent within the dataset. All data were reviewed and cleaned before analysis to improve the reliability of the results add quantitative validation methods. For qualitative data, interview responses were carefully reviewed, grouped and coded into themes. The same coding process was used throughout to ensure that similar responses were placed in the same categories. This made it easier to identify key patterns and insights add qualitative validation and coding procedures. The researcher clearly explained how participants were selected, where the data came from and how the results were analyzed. This improved transparency and made it possible for other researchers to review or repeat the study improve transparency explanation.

3.7. Data Analysis

The data were analyzed using Microsoft Excel (version 2019). Simple calculations such as totals, percentages and averages were used. This helped to show the amount of waste produced, the level of service coverage and the responses from different groups. The results were presented in a clear way so that the main findings were easy to understand.

4. Results

4.1. Waste Collection Methods

This section describes the different methods used by households in managing solid waste in Maseru City. Findings indicate that multiple collection methods are used, including municipal services, private providers and self-disposal at designated collection points. Re-

sults reveal that approximately a majority of households (around 60–70%) rely on house-to-house collection services, while the remaining households either use private collectors or transport their solid waste to designated collection points. In densely populated and informal settlements, reliance on designated collection points is higher due to limited access by collection vehicles. Analysis shows that households in well-planned areas with good road access are more likely to receive direct door-to-door services, whereas those in poorly planned areas depend more on shared collection points. This indicates a clear spatial inequality in service provision.

4.2. Collection Frequency

Findings indicate that the frequency of solid waste collection varies significantly across different areas of the city. Some households reported weekly collection, while others experienced bi-weekly or irregular services, as **Figure 1** illustrates the variation in collection frequency across different locations. Results reveal that approximately 50% of respondents receive weekly collection, while about 30% experience collection every two weeks and the remaining 20% report irregular or demand-based collection. Analysis shows that households located near main roads and central business areas receive more frequent services compared to those in peripheral or poorly accessible areas. The cause is linked to vehicle accessibility, fuel availability and scheduling efficiency. As a result, longer collection intervals lead to accumulation of solid waste in households, increasing risks such as odor, pests and unsanitary conditions.

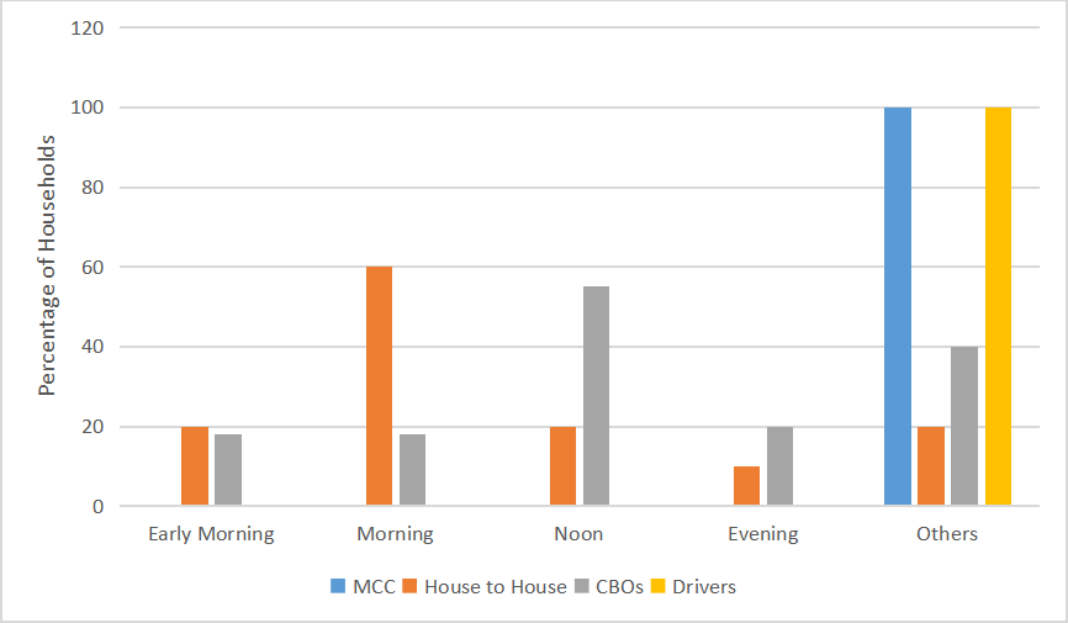

Figure 1. Garbage collection time.

4.3. Drop-Off Infrastructure (Designated Collection Points)

Draw a bar chart based on the following: Results reveal significant disparities in the availability and distribution of designated collection points across constituencies. Some areas have multiple accessible points, while others have limited or none. Quantitatively, constituencies with better infrastructure recorded higher usage of designated collection points (above 60%), whereas underserved areas recorded lower usage (below 30%) and higher instances of illegal dumping. **Figure 2** comprehensively illustrates the comparative distribution of these facilities across each respective area. Analysis shows that limited access to designated collection points directly contributes to improper disposal practices such as open dumping and burning of solid waste. This is more common in areas lacking formal service coverage.

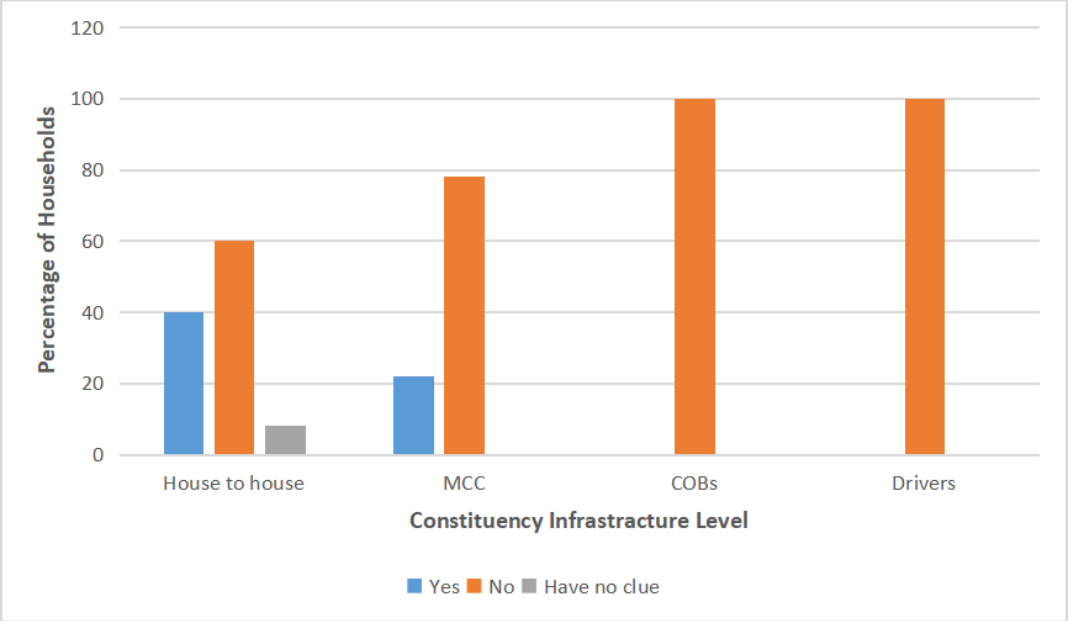

Figure 2. Drop off points.

4.4. Transportation Routes

Findings indicate that transportation routes for solid waste collection are unevenly distributed across Maseru City. Areas with well-maintained and connected roads have clearly defined and efficient routes, while informal settlements lack structured access routes. Results reveal that approximately 70% of collection routes operate within accessible road networks, while about 30% are constrained by poor or incomplete road infrastructure. **Figure 3** illustrates the distribution of these transport routes across various urban sectors. Analysis shows a strong relationship between road accessibility and service inequality. Areas with good road networks experience timely and regular waste collection, while poorly connected areas face delays or service exclusion. This suggests that infrastructure quality directly influences operational efficiency and equity in service delivery.

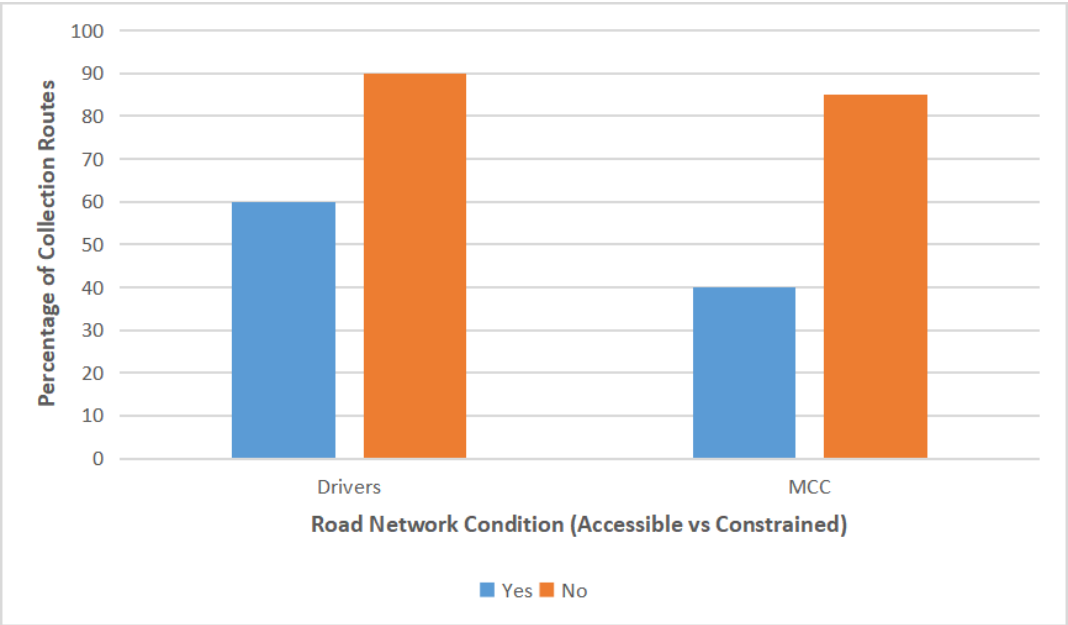

Figure 3. Movement paths.

4.5. Waste Generation and Household Factors

Results reveal that solid waste generation varies across households and constituencies. Weekly waste production differs depending on household size, income level and consumption patterns. Quantitative findings indicate that households with higher income levels tend to produce more mixed waste, including plastics, packaging materials and processed food residues, compared to lower-income households, which generate a higher proportion of organic waste. Findings indicate that while larger households generally produce more waste, income level has a stronger influence on waste composition and quantity. For example, households with 4–5 members sometimes generate more waste than larger households due to higher purchasing power. **Figure 4** presents the weekly amounts produced, clearly highlighting the differences between homes. Analysis shows that approximately 40–60% of variation in household waste generation can be attributed to socioeconomic differences rather than household size alone. This demonstrates that consumption behavior is a key driver of solid waste generation patterns.

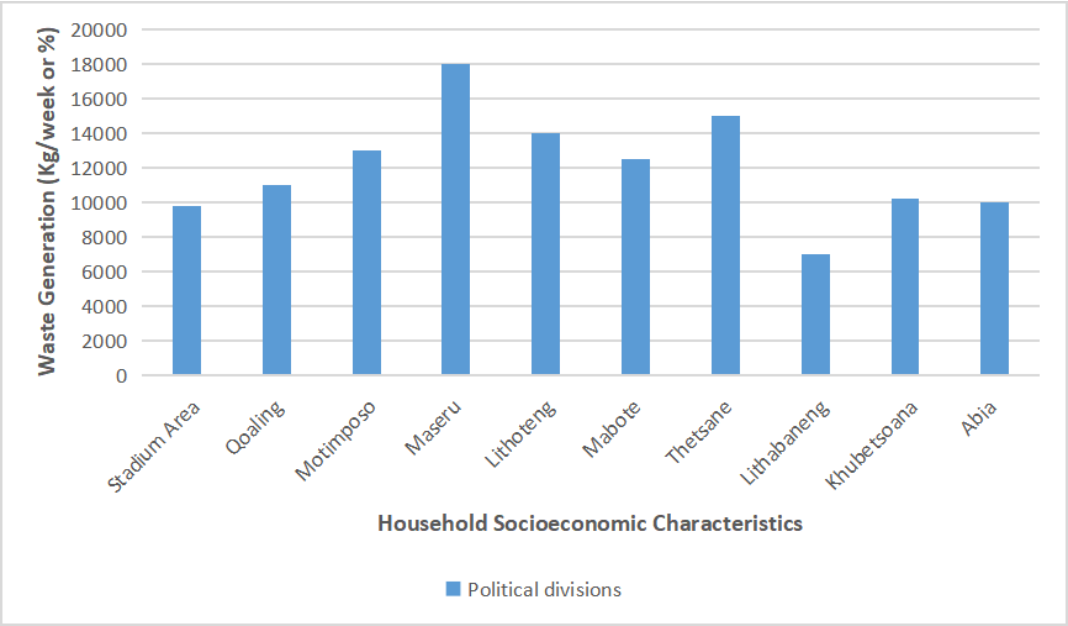

Figure 4. Garbage production in 7 days in each constituency.

5. Discussion

The findings from this study demonstrate that solid waste management in Maseru City is shaped by a combination of infrastructural, socioeconomic and institutional factors. The variation in collection methods highlights disparities in service delivery, where households in well-planned areas benefit from direct collection, while others rely on designated collection points due to limited access. The results further indicate that collection frequency is strongly influenced by road accessibility and operational capacity. Areas with better infrastructure receive more consistent services, whereas poorly connected areas experience irregular collection. This confirms that road access is a critical determinant of service equity, as it affects route efficiency, vehicle movement, and scheduling reliability.

In terms of waste generation, the study reveals that income levels play a more significant role than household size in determining the composition and volume of solid waste. Higher-income households tend to consume more packaged goods, resulting in increased plastic and non-organic waste, while lower-income households generate relatively more organic waste. This suggests that waste management strategies should consider socioeconomic diversity when designing interventions, as consumption patterns directly influence waste streams.

The disparities in designated collection points also

highlight systemic gaps in infrastructure planning. Limited access to these points in certain constituencies leads to illegal dumping and environmental degradation. This reinforces the need for spatially balanced service provision and improved planning. Transportation routes analysis shows that inefficiencies in road networks contribute to unequal service distribution. Poorly maintained or absent roads restrict access for collection vehicles, resulting in delayed or missed services. Therefore, infrastructure development is closely linked to operational performance in waste management systems.

Overall, the findings demonstrate that an integrated approach combining infrastructure improvement, equitable service distribution and socioeconomic considerations is necessary to enhance solid waste management in Maseru City. The study highlights that inefficiencies in one component of the system (e.g., roads, income disparities, or service access) have cascading effects on overall system performance and environmental outcomes.

6. Conclusions

The study showed that waste services in Maseru mainly use a house-to-house collection system managed by the city council together with community groups. Although this system works fairly well, it faces several challenges. These include limited service coverage in some areas, high service fees, poor road conditions and weak planning. As a result, waste collection is less efficient, and problems such as illegal dumping and environmental pollution are more common in underserved areas. To improve service delivery, there is a need for better coordination, more affordable fees and improved infrastructure. Stronger cooperation between the city council, community-based organizations and private operators can help expand service coverage and improve efficiency. In addition, investing in better road networks and waste management equipment would make it easier to reach difficult areas and reduce delays in waste collection.

This study contributes to the understanding of urban waste management in developing cities. It shows how institutional, financial and infrastructural challenges work together to limit the effectiveness of waste services. The study highlights the importance of using an integrated and system-based approach that combines community participation, better planning and targeted investment. The findings provide useful guidance for policymakers and urban planners who want to develop more inclusive, efficient and sustainable waste management systems, especially in fast-growing cities like Maseru study's contribution.

Future research should focus more on sustainable waste management practices such as waste reduction, reuse and recycling, in line with circular economy principles. There is also a need to improve waste governance by strengthening coordination between institutions, improving policy implementation and enforcing regulations. More studies are needed to ensure that waste services are well organized and fairly distributed across all areas of the city. Researchers should also explore payment systems that are affordable for residents while still supporting effective service delivery. In addition, future research should examine ways to support community-based groups by providing better equipment, transport and financial assistance. It is also important to study more efficient waste collection systems, such as better route planning and the use of temporary collection points, to reduce fuel use and operating costs. Research should further investigate the effects of waste burning and illegal dumping on human health and the environment. Finally, attention should be given to improving road networks and expanding services in poorly planned areas so that all residents can access waste services equally.

Based on the findings of the study, several practical measures are recommended to improve waste services in Maseru. The use of appropriate technologies can help improve efficiency, monitoring and decision-making introduces technology focus. First, stronger cooperation between the city council and community groups is needed, especially in areas with narrow streets or poor roads. Mobile-based reporting systems can be used to improve communication and allow residents to report missed collections or illegal dumping technology for coordination and communication Providing community groups with proper equipment, maintenance support and financial assistance would improve their perfor-

mance and reduce breakdowns. Simple systems can also be used to track equipment use and maintenance. Payment systems should be improved to make them more affordable and fair. The use of mobile money can make payments easier, increase transparency and reduce revenue losses technology for equipment management.

The study also recommends setting up temporary collection points to reduce travel time, fuel use and costs. Fixed collection schedules and clearly marked pickup points should guide residents. Better route planning can improve efficiency and tools such as Geographic Information Systems (GIS) can help design better routes and reduce costs technology for planning and routing. Finally, education and awareness programs are important to reduce waste burning and illegal dumping and to promote cleaner practices. Digital platforms such as social media and SMS can be used to reach more people and encourage positive behavior. In the future, smart waste technologies, such as sensor-based bins, can also be introduced to improve waste monitoring and collection efficiency technology for awareness and future smart solutions.

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Institutional Review Board Statement

Before collecting data, the researcher asked for permission from village or ward Chiefs. Approval processes differed depending on local leadership practices. The study followed ethical standards by explaining the purpose of the research, ensuring confidentiality.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data will be available on request from the author.

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Conflicts of Interest

The author declares no conflict of interest.

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