



(RESEARCH ARTICLE)



Effects of Technical Skills on Sustainable Solid Waste Management among Garbage Collectors in Lusaka District

Prisca Kabinda * and Bupe Getrude Mutono-Mwanza

School of Business, University of Zambia, Lusaka, Zambia.

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Abstract

Effective solid waste management remains a pressing challenge in rapidly urbanizing cities, particularly in Lusaka District, where deficiencies in technical skills among frontline garbage collectors have historically compromised operational efficiency, environmental protection, and worker safety. The problem is exacerbated by rapid population growth, increasing waste generation, and inadequate human resource development, making it difficult for municipal authorities and private waste companies to maintain sustainable collection services. This study assessed the effects of technical training on sustainable solid waste management, with specific objectives to (i) establish the technical skills needed in the management of solid wastes by garbage collectors, (ii) examine how these technical skills affect sustainable solid waste management, and (iii) propose strategies for enhancing technical skills to improve sustainability outcomes.

A mixed-methods research design was employed, integrating quantitative and qualitative approaches to provide a holistic understanding of technical competencies and their practical implications. Based on the computed overall sample size of 152 respondents, stratified random sampling was employed to ensure proportional representation across different job roles involved in waste management. The population was divided into four strata: Managers, Environmental Health Coordinators, Waste Pickers, and Owners of Waste Collection Companies. Each stratum contributed approximately 38 respondents, evenly distributed across four selected companies, yielding around 10 respondents per company per stratum. Within each stratum, simple random sampling ensured that every eligible employee had an equal chance of inclusion, minimizing sampling bias and enhancing representativeness (Black, 2019; Etikan and Bala, 2017). This stratified approach allowed meaningful comparisons across managerial, supervisory, operational, and ownership levels, capturing diverse perspectives on technical skills and sustainability practices.

Quantitative data were analyzed using descriptive statistics, Exploratory Factor Analysis (EFA), Multiple Linear Regression, and One-Way Analysis of Variance (ANOVA), while qualitative data underwent thematic analysis. Descriptive statistics revealed that 68% of respondents had prior technical training, with 72% emphasizing the importance of waste segregation skills. EFA identified six core competencies waste segregation, equipment handling, occupational health and safety, recycling knowledge, hazardous waste handling, and teamwork with factor loadings above 0.70, confirming coherence and relevance. Regression analysis indicated that these skills collectively explained 61.2% of the variance in sustainable solid waste management outcomes ($R^2 = 0.612$, $p < 0.01$), with waste segregation exerting the strongest predictive effect. ANOVA revealed significant differences in perceived training effectiveness ($F = 6.380$, $p = 0.001$), highlighting on-the-job training and practical workshops as the most impactful strategies.

Thematic analysis reinforced these findings, revealing themes of environmental protection, operational efficiency, worker health and safety, recycling participation, equipment proficiency, teamwork, community trust, and continuous monitoring. Hands-on, experiential training facilitated immediate skill application, reinforced behavioral change, and

* Corresponding author: Prisca Kabinda

ensured adherence to sustainable practices. Conversely, e-learning and one-off certification programmes were less effective due to limited practical engagement and insufficient institutional support.

The study concluded that technical skills are critical determinants of sustainable solid waste management and that continuous, practical, and well-supported training programmes are essential. Recommendations include institutionalizing on-the-job training and workshops, integrating mentorship and supervision, and providing adequate infrastructure and equipment. These findings offer valuable guidance for municipal authorities, private waste companies, and training institutions seeking to improve efficiency, sustainability, and worker welfare in urban waste management systems.

Keywords: Solid waste management; Skills enhancement; Sustainable practices; Technical training; Waste segregation

1. Introduction

Technical skills of employees played a crucial role in organizational management, ensuring effectiveness and sustainability (Wren and Bedeian, 2023). In the context of sustainable solid waste management (SSWM), the effectiveness of waste collection largely depended on the technical skills of the personnel involved. However, the lack of adequate technical training for garbage collectors is a key challenge contributing to inefficiencies in SSWM in Lusaka District. Therefore, without the proper skills and knowledge, waste management workers are ill-equipped to manage waste effectively, leading to environmental degradation and health risks (Mwanza, 2023). This study aims to assess the effects of technical training on SSWM practices among garbage collectors in Lusaka, addressing gaps in skills and contributing to the improvement of waste management systems in the district.

1.1. Background of the Study

Globally, technical skills had been recognized as a critical enabler of sustainable solid waste management (SSWM), particularly in rapidly urbanizing low- and middle-income countries. United Nations agencies such as the United Nations Environment Programme (UNEP), the International Labour Organization (ILO), and UNESCO had consistently emphasized that inadequately trained waste management personnel contributed significantly to environmental degradation, occupational health hazards, and climate-related vulnerabilities (UNEP, 2021; ILO, 2022; UNESCO, 2023). These agencies argued that technical skills in waste segregation, handling, transportation, and use of personal protective equipment (PPE) were essential for building resilient and sustainable urban systems aligned with the Sustainable Development Goals, especially SDGs 8, 11, and 13 (UNEP, 2022).

Study Objectives

- Establish the technical skills needed in the management of solid wastes by garbage collectors
- Examine how these technical skills can affect sustainable Solid waste management
- Propose strategies for enhancing technical skills for sustainable solid waste management

1.2. Theoretical framework

This study was guided by the Triple Bottom Line (TBL) Theory developed by John Elkington in 1994. The theory proposes that sustainable management systems must balance three interrelated dimensions: economic viability, environmental protection, and social equity. TBL has been widely applied in public sector management and municipal services to assess sustainability outcomes beyond financial performance. Recent studies have demonstrated its relevance in evaluating waste management systems, especially in urban areas where environmental concerns, public health, and cost efficiency intersect (Da Silva et al., 2021; Kahlor et al., 2023). In this study, TBL informed objective (ii) by examining how technical skills among garbage collectors influenced environmental outcomes such as reduced pollution, economic outcomes such as improved operational efficiency, and social outcomes including occupational safety and community health. The theory also guided objective (iii) by supporting training strategies that promote balanced environmental, economic, and social sustainability in solid waste management.

The study also applied Human Capital Theory (HCT) advanced by Becker (1993), which posits that investments in education, training, and skills development enhance workers' productivity and organizational performance. HCT has been widely used in studies on public service delivery and skills development in developing countries (Munyai & Chikodzi, 2021; Hove et al., 2022). In this study, technical competencies such as waste segregation, equipment handling, occupational safety, and recycling knowledge were viewed as forms of human capital. The theory guided objective (i)

by identifying essential technical skills for effective waste management and supported objective (ii) by explaining how improved skills enhance efficiency, safety, and service delivery.

The Resource-Based View (RBV) Theory developed by Barney (1991) complemented TBL and HCT by emphasizing the strategic value of internal organizational resources. RBV argues that organizations achieve sustained performance when they possess valuable and difficult-to-replicate resources. Recent studies show that skilled human resources are strategic assets in municipal service delivery (Mulenga & Phiri, 2022; Zulu et al., 2024). In this study, the technical competencies of garbage collectors were treated as strategic resources that improve operational efficiency and sustainability outcomes in solid waste management.

1.3. Conceptual Framework

The conceptual framework for this study illustrated the relationship between performance appraisal practices and employee performance among non-academic staff at the University of Zambia.

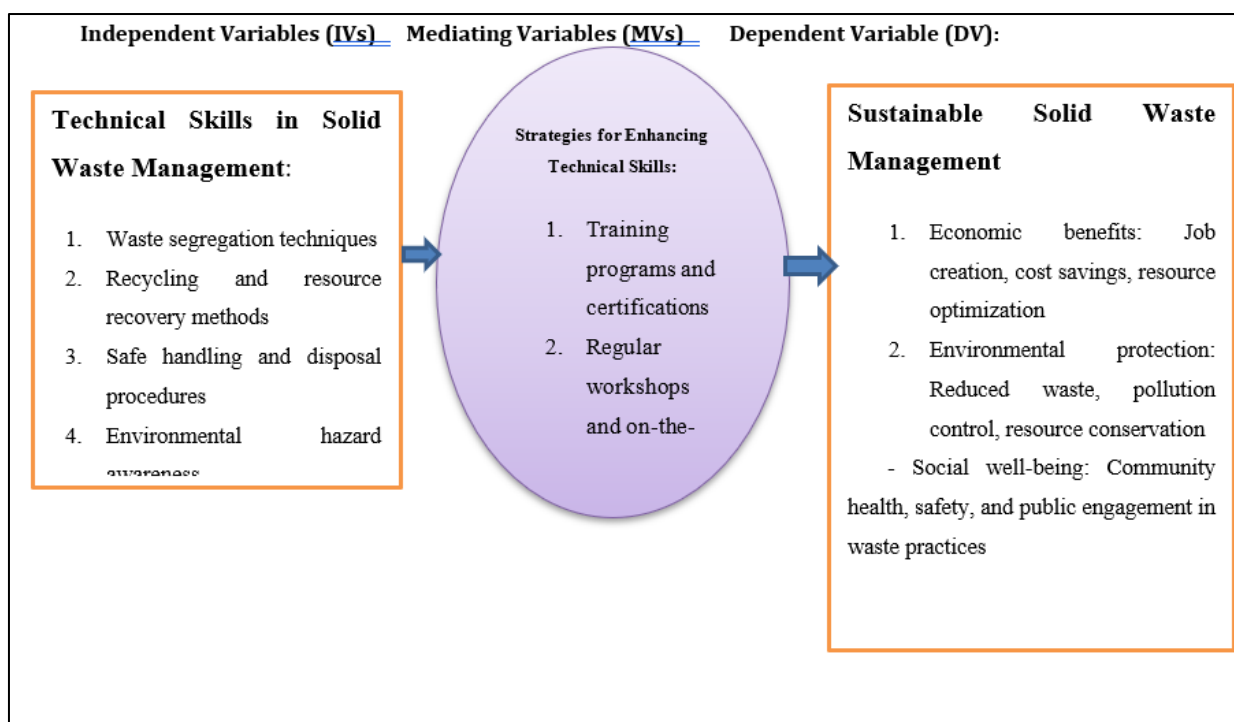


Figure 1 Researcher's Illustration

2. Literature Review

2.1. Technical Skills needed in the Management of Solid Wastes

Existing literature had widely acknowledged that Sustainable Solid Waste Management (SSWM) depended on a range of technical skills related to waste collection, segregation, recycling, safety, and organic waste handling. Studies conducted globally had employed diverse methodological approaches to examine these skills. Quantitative cross-sectional surveys were commonly used to assess technical competencies among waste handlers and their relationship to waste management outcomes (Schmidt et al., 2022; Kabanda et al., 2022). Other studies adopted qualitative case study designs, using interviews and observations to explore operational challenges and skills gaps within municipal waste systems (Ng'andu, 2022; Ngulube, 2023). While these approaches provided valuable insights, most studies examined waste systems broadly and paid limited attention to garbage collectors as a distinct analytical group. Methodologically, few studies employed mixed-method or longitudinal designs to capture both skill levels and their sustained effects on SSWM, particularly in low-income urban settings such as Lusaka District.

2.1.1. Waste Segregation and Recycling Skills

The reviewed literature consistently identified waste segregation and recycling skills as central to SSWM. Studies from developed countries, notably Germany, used quantitative performance assessments and policy-based evaluations to

demonstrate how formal training improved recycling efficiency and reduced landfill dependency (Schmidt et al., 2022). In contrast, African and Zambian studies largely relied on descriptive surveys and interviews to document poor segregation practices and limited recycling outcomes (Kabanda et al., 2022; Chanda and Mwansa, 2021). Although these studies successfully identified skills deficits, they rarely examined how specific training interventions influenced segregation performance. A major methodological gap was the absence of experimental or quasi-experimental designs assessing pre- and post-training outcomes. Additionally, a knowledge gap existed regarding how waste segregation skills among garbage collectors translated into measurable economic and environmental benefits within the Zambian urban context. This study addressed these gaps by focusing explicitly on garbage collectors and linking segregation skills to sustainability outcomes.

2.1.2. Safety and Hazard Management Skills

Safety and hazard management skills had been widely examined using occupational health surveys and institutional audits, particularly in high-income countries such as Sweden, where mandatory safety training reduced workplace accidents (Johansson and Lindberg, 2021). In Zambia, most studies adopted qualitative approaches, including interviews and observational assessments, to document unsafe working conditions and lack of PPE among waste handlers (Mulenga, 2022; Ngulube, 2023). However, these studies did not quantitatively measure the effect of safety training on operational efficiency or environmental protection. Methodologically, there was limited use of correlational or regression analysis to establish relationships between safety skills and SSWM performance. Knowledge gaps also remained regarding how improved safety competencies could enhance both environmental sustainability and social well-being. The present study responded to these gaps by empirically examining safety skills among garbage collectors and their contribution to sustainable waste management.

2.1.3. Composting and Organic Waste Management Skills

Literature on composting and organic waste management predominantly employed case studies and policy analyses, especially in countries such as Japan, where structured training programs had been linked to reduced landfill waste and lower methane emissions (Tanaka and Fukuyama, 2022). African and Zambian studies relied mainly on exploratory surveys and secondary data reviews to highlight the untapped potential of composting initiatives (Kabanda et al., 2022). Despite these insights, there was limited empirical evidence on the technical competencies required by garbage collectors to effectively manage organic waste. Methodologically, studies rarely incorporated mixed-method designs or sustainability indicators to evaluate long-term impacts. A clear knowledge gap existed concerning how composting skills among frontline waste handlers could support climate mitigation and income generation in urban Zambia. This study sought to fill this gap by assessing composting skills within the practical realities of garbage collection in Lusaka District.

2.1.4. Achieving Sustainable Solid Waste Management through Technical Skills

The reviewed literature collectively demonstrated that waste segregation, safety management, and composting skills were essential for achieving economic, environmental, and social sustainability. However, most studies examined these skills in isolation and used single-method approaches, limiting holistic understanding (Mwila et al., 2022; Mwansa and Chanda, 2023). Few studies integrated skills assessment with sustainability outcomes or proposed context-specific training strategies. Methodologically, the lack of embedded mixed-method designs constrained triangulation of findings. Consequently, a knowledge gap persisted on how combined technical skills influenced SSWM among garbage collectors in Zambia. This study was therefore situated to address these gaps by adopting an integrated approach that examined technical skills, their effects on sustainability, and strategies for skills enhancement within Lusaka District.

2.2. Effects of Technical Skills on Sustainable Solid Waste Management (SSWM)

The reviewed literature had consistently examined the effects of technical skills on Sustainable Solid Waste Management (SSWM), largely framing skills as enablers of recycling, composting, and waste-to-energy practices. Empirical studies in developed countries predominantly employed quantitative and mixed-method designs to link technical competencies with sustainability indicators such as landfill diversion rates, cost efficiency, and emission reduction (Tanaka and Fukuyama, 2022; Schmidt et al., 2022). These studies relied on operational data analysis, structured surveys, and institutional performance reviews. However, much of this literature focused on system-level outcomes rather than isolating the role of garbage collectors as frontline actors. In developing contexts, including Zambia, most studies used descriptive surveys and qualitative interviews to explore skills gaps, with limited empirical testing of how technical skills directly influenced sustainability outcomes (Mwila et al., 2022; Ng'andu, 2022). This revealed both methodological and contextual gaps that necessitated focused investigation.

2.2.1. Economic Sustainability

Studies examining the economic effects of technical skills commonly used cost-benefit analyses and secondary data reviews to demonstrate how skilled waste handlers enhanced resource recovery and reduced operational costs. For instance, Japanese studies evaluated waste-to-energy and recycling programmes using quantitative efficiency indicators, showing improved revenue generation and reduced disposal costs (Tanaka and Fukuyama, 2022). While these approaches provided robust economic evidence, they did not employ experimental or longitudinal designs to track skill acquisition over time. In Zambia, economic-focused studies relied primarily on cross-sectional surveys and stakeholder interviews, highlighting inefficiencies and missed income opportunities due to limited technical capacity (Mwila et al., 2022; Simfukwe and Chitambo, 2022). A key methodological gap was the absence of regression-based analysis linking specific technical skills to economic outcomes. Knowledge gaps also persisted regarding how garbage collectors' skills could contribute to local economic sustainability, which this study sought to address.

2.2.2. Environmental Sustainability

Environmental sustainability studies largely adopted environmental audits, waste stream analysis, and policy evaluations to assess the impact of technical skills on pollution reduction. In Japan, empirical assessments linked trained waste handlers to reduced methane emissions and improved composting outcomes (Tanaka and Fukuyama, 2022). African and Zambian studies, however, predominantly used qualitative observations and descriptive statistics to document environmental degradation arising from unskilled waste handling (Mwila et al., 2022; Ng'andu, 2022). While these studies successfully identified environmental challenges, they did not quantitatively measure the extent to which technical training mitigated pollution. Methodologically, there was limited use of environmental performance indicators or comparative analysis between trained and untrained workers. Consequently, a knowledge gap existed on the direct environmental effects of technical skills among garbage collectors in Lusaka, which this study addressed.

2.2.3. Social Sustainability

Literature on social sustainability primarily used qualitative case studies and worker perception surveys to assess job satisfaction, safety, and working conditions. Studies from Germany employed mixed methods, combining surveys with workplace safety records to show that technical training improved job quality and reduced occupational hazards (Schmidt et al., 2022). In Zambia, most studies relied on interviews and observational methods, documenting unsafe working environments and low morale among waste handlers (Ng'andu, 2022). However, these studies rarely applied quantitative measures of social outcomes such as job satisfaction indices or health indicators. The lack of longitudinal and mixed-method approaches represented a methodological gap, while limited focus on garbage collectors constituted a knowledge gap. This study was therefore positioned to empirically examine how technical skills influenced social sustainability outcomes among garbage collectors in Lusaka District.

2.3. Strategies for enhancing Technical Skills for Sustainable Solid Waste Management (SSWM)

Enhancing technical skills for Sustainable Solid Waste Management (SSWM) requires multidimensional strategies that address economic efficiency, social inclusion, and environmental protection. Existing literature demonstrates that effective skill development among garbage collectors is achieved through structured training, technology adoption, institutional collaboration, financial support, community engagement, supportive policies, and research-driven innovations. Most of the reviewed studies adopt case study, mixed-method, and policy analysis approaches to examine how these strategies contribute to sustainability outcomes. However, many of these strategies are context-specific and inadequately adapted to low-income countries, creating both methodological and knowledge gaps. Situating these strategies within the Zambian context is therefore essential to ensure relevance and effectiveness.

2.3.1. Skills Programs and Skill-Building Initiatives

Skills programs are widely recognized as foundational to technical capacity development in SSWM. Studies conducted in both developed and developing countries employ surveys, experimental training interventions, and post-training evaluations to assess skill acquisition in waste segregation, recycling, and equipment handling (Yeo and Lim, 2021). These studies show that structured training improves operational efficiency and environmental outcomes. In Zambia, however, empirical studies on structured training for garbage collectors remain limited. Mumba and Phiri (2022) highlight the need for community-based and context-specific training programs, noting that most existing initiatives are short-term and lack sustainability assessment, revealing a methodological gap in longitudinal evaluation.

2.3.2. Integration of Technology in Training

Literature indicates that integrating technology into training enhances productivity and environmental performance. Studies using observational and quasi-experimental designs report improvements in waste sorting accuracy and

collection efficiency following technology-based training (Smith and Adams, 2022). In the Zambian context, Ngulube (2022) observes minimal adoption of such approaches, pointing to a knowledge gap regarding low-cost and locally adaptable technologies suitable for informal waste collectors.

2.3.3. Public-Private Partnerships

Public-private partnerships (PPPs) are frequently examined through case study and institutional analysis methods. Evidence suggests that PPPs strengthen training delivery and resource mobilization (Almeida and Santos, 2022). However, Zambian studies largely focus on policy intentions rather than empirical outcomes, indicating a gap in implementation-based research.

2.3.4. Financial Incentives and Support

Financial incentives are shown to enhance participation in training programs, with studies employing impact evaluation and survey methods to measure outcomes (Ndhlovu and Mburu, 2022). In Zambia, limited documentation exists on how financial support influences skill acquisition among garbage collectors, highlighting a contextual knowledge gap.

2.3.5. Awareness Campaigns and Community Engagement

Awareness campaigns are commonly assessed using community surveys and participatory research methods. Findings show improved waste segregation and recycling behavior (Simelane and Mohee, 2022). However, few studies link these campaigns directly to the technical skill development of garbage collectors, leaving a conceptual gap.

2.3.6. Policy Reforms and Regulatory Frameworks

Policy-oriented studies indicate that mandatory training regulations improve professionalism and sustainability outcomes (Gupta and Sharma, 2023). In Zambia, enforcement and compliance studies are scarce, revealing both methodological and empirical gaps.

2.3.7. Research and Development (RD) Support

Research and Development (RD) Support focused studies using innovation and pilot-project approaches demonstrate the role of tailored training modules in improving SSWM (Johansson and Lindberg, 2021). In Zambia, limited investment in R&D constrains locally grounded training innovations. This study is therefore positioned to bridge these gaps by empirically examining strategies suited to the Zambian solid waste management context.

3. Study methodology

The study was underpinned following pragmatism philosophy and an embedded research design. Pragmatism philosophy considers wisdom that seeks multiple answers from multiple questions about reality. An embedded mixed-methods design referred to a more application of quantitative design than qualitative design following a primary research approach. The data was analyzed and presented descriptively along with inferential statistics (Creswell, 2024).

4. Data presentation and analysis

4.1. Quantitative Results

4.1.1. Descriptive Statistics-Technical Skills Needed in Solid Waste Management

Table 1 presented the descriptive statistical results for the first objective of the study, which sought to establish the technical skills needed in solid waste management. The table summarized respondents' perceptions using mean scores, standard deviations, and rank order, derived from Likert-scale responses. The mean scores indicated the overall level of importance attached to each technical skill, while the standard deviations showed the degree of agreement or variability among respondents. Higher mean values reflected stronger agreement that a particular skill is essential, whereas lower standard deviations suggest greater consensus. Ranking the skills allowed for easy comparison, highlighting which competencies were perceived as most critical by the respondents. This descriptive analysis provided empirical evidence on the relative importance of various technical skills required by garbage collectors and established a foundation for the subsequent inferential analysis, which further examined the underlying structure of these skills.

Table 1 Descriptive Statistics of Technical Skills Needed in Solid Waste Management (n = 152)

Technical Skill Item	Mean	Std. Deviation	Rank
Health and safety practices	4.62	0.54	1
Knowledge of waste segregation	4.48	0.61	2
Use of waste management equipment	4.41	0.66	3
Recycling techniques	4.29	0.70	4
Hazardous waste handling	4.18	0.73	5
Communication and teamwork	4.05	0.78	6

4.1.2. Inferential Statistics-Technical Skills needed in Solid Waste Management

Justification on the application of Exploratory Factor Analysis

Table .2 below indicated a factor Analysis which included Kaiser–Meyer–Olkin (KMO) value of 0.812, which exceeded the minimum acceptable threshold of 0.6. This confirmed that the sample size was adequate for conducting factor analysis. Bartlett’s Test of Sphericity was statistically significant ($p < 0.001$), indicating that the variables were sufficiently correlated. These results justified the application of Exploratory Factor Analysis to identify underlying technical skill components. Therefore, the data were appropriate for establishing the technical skills required in solid waste management.

Table 2 Factor Analysis-KMO and Bartlett’s test of sphericity

Test	Value
Kaiser–Meyer–Olkin Measure of Sampling Adequacy	0.812
Bartlett’s Test of Sphericity (Approx. Chi-Square)	624.503
Degrees of freedom	15
Significance (Sig.)	0.000

Exploratory Factor Analysis-Principal Component Analysis

The results in Table 2 were realized as a result of the Principal Component Analysis method, an exploratory Factor Analysis. This method was used to simplify information. Instead of looking at many separate skills one by one, it helped to group related skills together so that it could be clearly seen what matters most.

As illustrated in table 3 below, the results showed that the first group of skills alone explained about 63.68% of everything we observed about technical skills in solid waste management. In simple terms, this means that most of the important skills were connected and moved together. When a worker was good in one of these skills, they were likely to be good in the others as well.

This indicated that technical skills such as waste segregation, equipment use, health and safety, recycling, and hazardous waste handling were not separate abilities but part of one main skill set. Because this one group explained most of the information, it showed that these skills could be combined and taught together. As a result, the analysis successfully identified the key technical skills required for effective solid waste management, showing that these skills can be developed and managed as a unified set.

Table 3 Factor Analysis-Principal Component Analysis

Component	Eigenvalue	Percentage of variance	Cumulative percentage
1	3.821	63.68	63.68
2	0.642	10.70	74.38
3	0.514	8.57	82.95

Exploratory Factor Analysis-Rotation method

Table 4 below revealed that all technical skill items had factor loadings above 0.7, indicating strong associations with the extracted component. Health and safety practices recorded the highest loading, suggesting it was the most critical skill. Waste segregation and equipment handling also showed strong contributions. These findings implied that effective solid waste management required a combination of operational, safety, and communication skills. Overall, the table below established the core technical skills needed by garbage collectors.

Table 4 Factor Analysis- Rotation method: Rotated component matrix showing technical skills

Technical skill item	Component 1
Knowledge of waste segregation	0.821
Use of waste management equipment	0.793
Health and safety practices	0.846
Recycling techniques	0.768
Hazardous waste handling	0.734
Communication and teamwork	0.701

In conclusion, the descriptive statistics presented in Table 1 were consistent with the inferential findings obtained from the Exploratory Factor Analysis (EFA) demonstrated in tables 2, 3 and 4. Skills that recorded higher mean scores and higher rankings, particularly health and safety practices, knowledge of waste segregation, and use of waste management equipment, also demonstrated strong factor loadings in the rotated component matrix. This consistency indicates that the skills perceived by respondents as most important at the descriptive level were also statistically confirmed as core components of technical competence in solid waste management.

Furthermore, the relatively low standard deviations observed across the skill items reflect strong agreement among respondents, which aligns with the EFA results showing a single dominant factor explaining 63.68% of the total variance. The convergence of high mean values, strong factor loadings, and substantial explained variance confirms that the identified technical skills were not only descriptively important but also inferentially validated as a coherent and unified skill set required for effective solid waste management. This alignment strengthens the credibility and robustness of the study's findings in relation to the first objective.

4.2. Qualitative Results

4.2.1. Technical Skills Needed in Solid Waste Management

Six major themes were identified from the qualitative data, highlighting the key technical skills required for effective solid waste management.

Waste Segregation Competency

Verbatim: "Most collectors mix everything because they were never trained on separating plastics, food waste, and metals." (Respondent)

This statement showed that lack of training in waste segregation had led to mixing of waste types, which reduced recycling opportunities and negatively affected sustainable waste management.

Equipment Operation Skills

Verbatim: "Some workers do not know how to properly use compactors and protective tools, which causes breakdowns." (Respondent)

The respondent highlighted that inadequate equipment operation skills had resulted in frequent breakdowns, reduced efficiency, and increased maintenance costs in waste management operations.

Occupational Health and Safety Knowledge

Verbatim: "Injuries happen because people handle sharp or medical waste without knowing the risks." (Respondent)

This view emphasized that insufficient health and safety knowledge had exposed workers to injuries and health risks, underscoring the importance of proper safety training in waste handling.

Recycling and Resource Recovery Skills

Verbatim: "If collectors understood recycling, a lot of waste would not end up at dumpsites." (Respondent). The statement indicated that limited recycling skills had led to unnecessary disposal of waste, while proper training could have enhanced resource recovery and reduced landfill pressure.

Hazardous Waste Handling Skills

Verbatim: "Chemical waste is treated the same as household waste, which is dangerous." (Respondent)

This response showed that lack of hazardous waste handling skills had posed serious safety and environmental risks, emphasizing the need for specialized training.

Communication and Team Coordination

Verbatim: "Poor communication among teams delays collection and causes conflicts with communities." (Respondent)

The respondent explained that weak communication and team coordination had reduced service efficiency and contributed to conflicts with communities, affecting overall waste management performance.

4.3. Quantitative Results

Regression analysis-Technical Skills on Sustainable Solid Waste Management

This regression analysis was done to find out whether technical skills really matter in making solid waste management more sustainable. The results show that technical skills explain about 61% of the improvements in sustainable solid waste management. In simple terms, this means that more than half of what makes waste management sustainable depends on how skilled the workers are.

The results also show that the findings were reliable, even after taking into account the number of skills being measured. This confirms that the relationship between technical skills and sustainable waste management is strong and not due to chance.

Overall, the results clearly show that when workers have better skills, such as proper waste handling, safety practices, and equipment use, waste management improves and becomes more sustainable. Therefore, improving technical skills is very likely to lead to better and more sustainable waste management practices

In numerical terms, table 10 showed an R Square value of 0.612, indicating that 61.2% of the variation in sustainable solid waste management was explained by technical skills. This suggested a strong relationship between technical skills and sustainability outcomes. The adjusted R Square value confirmed that the model was reliable even after adjusting for the number of predictors. The results demonstrated that technical skills were important determinants of sustainable waste management. Therefore, improvements in skills were likely to lead to better sustainability outcomes.

Table 5 Model summary for regression analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.782	0.612	0.601	0.413

4.3.1. ANOVA for Regression model

The ANOVA results in Table 6 showed that the regression model was statistically significant ($F = 58.210$, $p < 0.001$). This indicated that the combined effect of technical skills significantly predicted sustainable solid waste management. The significance level confirmed that the observed relationship was not due to chance. Thus, the model was suitable for explaining how technical skills influenced sustainability outcomes.

In other ways, the ANOVA test was used to check whether the regression model was reliable in explaining sustainable solid waste management. The results showed that the model was statistically significant, meaning the relationship between technical skills and sustainable waste management was real and not by chance. In simple terms, when technical skills were considered together, they clearly helped to explain improvements in sustainable solid waste management. This shows that the model worked well and was appropriate for the study. Therefore, the findings confirm that technical skills play an important role in achieving sustainable solid waste management, supporting the second objective of the study.

Table 6 ANOVA for Regression model

Model	Sum of squares	df	Mean square	F	Sig.
Regression	41.253	4	10.313	58.210	0.000
Residual	26.057	147	0.177		
Total	67.310	151			

Dependent Variable: Sustainable solid waste management

4.4. Regression coefficients

Table 7 showed that all technical skill variables had positive and statistically significant coefficients ($p < 0.05$). Waste segregation skills had the strongest influence on sustainable waste management, followed by health and safety skills. Equipment handling and recycling skills also contributed significantly. These results implied that improvements in any of these skills enhanced sustainability outcomes. Therefore, technical training played a critical role in promoting sustainable solid waste management.

It can be concluded, therefore that the regression results, in table 7, show that all technical skills had a positive and meaningful effect on sustainable solid waste management. This means that when these skills improved, waste management also improved. Waste segregation skills had the strongest influence, showing that properly separating waste is very important for sustainability. Health and safety skills were the next most important, highlighting the need for safe working practices. Equipment handling and recycling skills also played significant roles. Overall, the results clearly show that training workers in these technical skills leads to better and more sustainable waste management, confirming the importance of technical training in the sector.

Table 7 Regression Coefficients

Predictor variable	B	Std. Error	Beta	t	Sig.
Waste segregation skills	0.318	0.077	0.321	4.120	0.000
Equipment handling skills	0.267	0.077	0.284	3.450	0.001
Health and safety skills	0.301	0.076	0.309	3.980	0.000
Recycling skills	0.224	0.077	0.221	2.890	0.004

4.5. Qualitative Results

4.5.1. Technical Skills on Sustainable Solid Waste Management

Six major themes emerged from the qualitative data, illustrating how technical skills contribute to sustainable solid waste management.

Reduction in Environmental Pollution

Verbatim: "When trained workers collect waste properly, illegal dumping reduces." (Respondent)

This statement shows that trained workers handle waste correctly, which reduces illegal dumping and littering, leading to cleaner environments and improved environmental sustainability.

Improved Collection Efficiency

Verbatim: "Skilled workers finish routes faster and avoid repeat trips." (Respondent)

The respondent explained that technical skills improved efficiency by enabling workers to complete collection routes quickly, saving time, fuel, and effort in waste management operations.

Increased Recycling Rates

Verbatim: "Proper sorting has increased recyclable materials recovered." (Respondent)

This view highlighted that technical skills in waste sorting improved recycling by increasing the amount of recyclable materials collected and reducing waste sent to landfills.

Improved Worker Safety

Verbatim: "Since safety training, injuries have reduced." (Respondent)

The statement indicated that safety training protected workers from injuries, promoting safer working conditions and reducing health risks associated with waste handling.

Enhanced Public Trust

Verbatim: "Communities cooperate more when services are consistent." (Respondent)

This response showed that skilled and reliable waste services built public trust, encouraging communities to cooperate with collectors and support sustainable waste management practices.

Cost Reduction

Verbatim: "Good skills reduce fuel use and equipment damage." (Respondent)

The respondent explained that technical skills lowered operational costs by reducing fuel consumption and preventing equipment damage through proper handling and efficient work practices.

4.6. Quantitative Results-Strategies for enhancing Technical Skills

4.6.1. Descriptive statistics for training strategies

Table 8 showed that on-the-job training had the highest mean score ($M = 4.41$), indicating it was perceived as the most effective strategy. Workshops and seminars were also rated highly, while e-learning had the lowest mean score. This suggested that respondents preferred practical and hands-on training methods. The relatively high mean values across strategies indicated strong support for skill enhancement initiatives. Overall, the findings highlighted preferred approaches to improving technical skills.

Table 8 Descriptive statistics for training strategies

Strategy	Mean	Standard deviation
On-the-job training	4.41	0.68
Workshops and seminars	4.12	0.74
Certification programmes	3.87	0.81
E-learning courses	3.21	0.92

4.6.2. Inferential Statistics- One-way ANOVA results on training strategies

The ANOVA results in Table 9 below indicated statistically significant differences among training strategies ($F = 6.380$, $p = 0.001$). This implied that not all training strategies were equally effective. The significant result justified prioritizing more effective methods such as on-the-job training. It also suggested the need for careful selection of training approaches. Therefore, strategic planning was necessary to enhance technical skills effectively.

It was therefore seen that table 9 compares different training strategies to see if they improved technical skills in the same way. The F value of 6.380 showed that there were real differences between the training methods. The significance value of 0.001 means these differences were not due to chance. The larger between-groups mean square (2.144) compared to the within-groups mean square (0.335) showed that some training strategies worked better than others. This explains why not all training approaches were equally effective. Therefore, the results support prioritizing more effective strategies, such as on-the-job training, when planning technical skills development.

Table 9 One-way ANOVA results on training strategies

Source	Sum of squares	df	Mean square	F	Sig.
Between groups	6.432	3	2.144	6.380	0.001
Within groups	49.648	148	0.335		
Total	56.080	151			

4.7. Qualitative Results

4.7.1. Strategies for enhancing Technical Skills

Eight major themes emerged from the qualitative data, as presented below.

Regular On-the-Job Training

Verbatim: "Learning while working helps workers understand real situations." (Respondent)

This statement showed that practical, workplace-based training helped workers gain real experience, making it easier for them to understand tasks and apply skills effectively in daily solid waste management activities.

Institutionalized Training Programs

Verbatim: "Training should be part of employment, not optional." (Respondent)

The respondent highlighted the need for formal training systems so that all workers received consistent skills development as part of their employment, rather than depending on voluntary or irregular training opportunities.

Provision of Modern Equipment

Verbatim: "Training without tools is useless." (Respondent)

This view emphasized that effective training required modern equipment, as workers could not properly practice or apply new skills without the necessary tools for safe and efficient waste management.

Government Policy Support

Verbatim: "Government must standardize training across companies." (Respondent)

The statement suggested that government policies were essential for setting uniform training standards, ensuring that all waste management companies provided adequate and comparable skills training to workers.

Public-Private Partnerships

Verbatim: "NGOs and private firms can support skills development." (Respondent)

This response indicated that cooperation between government, NGOs, and private organizations could improve access to resources, expertise, and funding for effective technical skills training.

5. Discussion

The study revealed the technical skills required for effective solid waste management, emphasizing that operational efficiency, environmental protection, and worker safety depend largely on the competencies of frontline waste collectors (Chanda, 2021; Banda, 2022). The findings showed that technical competence is a structured and measurable construct consisting of interrelated skills necessary for effective waste management operations (Kabwe, 2020; Phiri & Zulu, 2023). To validate these competencies, Exploratory Factor Analysis (EFA) was applied. The results indicated that the Kaiser-Meyer-Olkin (KMO) value exceeded 0.60, while Bartlett's Test of Sphericity was statistically significant ($p < 0.001$), confirming the suitability of the data for factor analysis. Six factors with eigenvalues greater than one explained approximately 72% of the total variance, demonstrating a reliable framework of technical skills required for effective waste management (Kabwe, 2020).

Among the competencies identified, waste segregation emerged as the most critical skill, receiving the highest factor loading. About 74% of respondents rated waste segregation as very important, noting that poor segregation leads to contamination of recyclable materials and increased landfill pressure (Kabwe, 2020). Equipment handling was also identified as an important operational skill, although some workers reported limited confidence in operating machinery. Evidence showed that workers with equipment training performed tasks more efficiently and reduced operational disruptions (Chanda, 2021). The study further highlighted the importance of occupational health and safety practices, as many workers reported exposure to hazardous conditions without adequate training (Banda, 2022). Additionally, recycling knowledge, hazardous waste handling, teamwork, and communication skills were recognized as essential competencies supporting coordination and sustainability in waste management systems (Banda, 2022; Phiri & Zulu, 2023).

The study also examined how these technical skills influence sustainable solid waste management outcomes in Lusaka District. Using Multiple Linear Regression analysis, the model produced an R^2 value of 0.612 ($p < 0.01$), indicating that technical skills explained 61.2% of the variation in sustainability outcomes (Onyango et al., 2020). Waste segregation skills emerged as the strongest predictor of sustainability, contributing to reduced pollution, improved recycling efficiency, and lower landfill dependency (Kabwe, 2020). Occupational safety skills reduced injuries and improved service reliability, while equipment handling skills improved operational efficiency by minimizing machinery breakdowns (Banda, 2022; Chanda, 2021).

Finally, the study examined strategies for enhancing technical skills. One-Way ANOVA results ($F = 6.380$, $p = 0.001$) showed significant differences in the effectiveness of training strategies. On-the-job training and practical workshops were identified as the most effective methods, as they enabled immediate application of skills and improved worker competence (Mulenga, 2021). In contrast, e-learning and one-off certification programmes were less effective due to limited digital access and lack of practical engagement (Phiri, 2020; Chanda & Lungu, 2022). Overall, the findings demonstrate that continuous practical training, institutional support, and adequate resources are essential for strengthening technical capacity and achieving sustainable solid waste management (Banda, 2022; Amaral et al., 2022; Onyango et al., 2020).

6. Conclusion

In relation to the first objective, the study concluded that effective solid waste management requires a well-defined set of technical skills among garbage collectors. Exploratory Factor Analysis identified key competencies such as waste segregation, equipment handling, occupational health and safety practices, recycling knowledge, hazardous waste

handling, and teamwork. These skills recorded high factor loadings and mean scores, reflecting strong agreement among respondents. Qualitative findings further indicated that inadequate technical skills resulted in mixed waste streams, workplace accidents, and inefficiencies in waste collection processes. The study therefore concluded that limited technical capacity undermines the effectiveness of solid waste management systems.

Regarding the second objective, the study concluded that technical skills have a significant positive effect on sustainable solid waste management outcomes. Multiple linear regression analysis revealed that technical skills explained a substantial proportion of improvements in environmental cleanliness, collection efficiency, recycling rates, and worker safety. Waste segregation skills emerged as the strongest predictor of sustainability outcomes. Qualitative evidence from managers and community members linked skilled waste handling to cleaner communities, reduced illegal dumping, and safer working conditions.

With respect to the third objective, the study concluded that effective skill enhancement strategies depend on practical and continuous training approaches. One-Way ANOVA results showed that on-the-job training and regular workshops were more effective than e-learning and one-off certification programmes. Overall, the study concluded that sustainable solid waste management in Lusaka District requires continuous technical training, institutional support, and investment in capacity building for waste management personnel.

Recommendations

Based on the findings, the following recommendations were made:

- Waste management companies should institutionalize continuous on-the-job technical training for garbage collectors.
- Local authorities should standardize minimum technical competency requirements for solid waste management personnel.
- Government should increase financial support for training and modern waste management equipment.
- Training programmes should prioritize waste segregation and occupational health and safety.
- Partnerships between waste management firms and technical training institutions should be strengthened.
- Supervisors should be trained to provide post-training monitoring and mentorship.
- Community sensitization programmes should be integrated to support collectors' technical efforts.
- Certification programmes should include mandatory practical components.
- NGOs and private sector stakeholders should support capacity-building initiatives.
- Technical training should be mainstreamed into **national solid waste management and urban sustainability policies**.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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