



Determinants of financial sustainability in private solid waste management firms: Evidence from Dar es Salaam, Tanzania using System GMM

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ABSTRACT

Financial sustainability is fundamental to the survival and continuity of private solid waste management (SWM) firms, yet evidence on its determinants remains limited, particularly in developing countries such as Tanzania. This study examines the determinants of financial sustainability among private SWM firms in Dar es Salaam using an unbalanced panel dataset of 36 firms from 2016 to 2023. Guided by Contingency Theory and Sustainability Finance Theory, the study employed a longitudinal panel research design. Financial sustainability was measured using the Financial Self-Sufficiency (FSS) ratio, while its determinants were analysed using the two-step System Generalised Method of Moments (System GMM) estimator. The results show that financial sustainability is persistent over time ($\beta = 0.572$, $p < 0.01$). Firm age, firm size, adoption of new technology, container-based collection, operation in planned areas, customers served, and waste collection frequency have positive and statistically significant effects on financial sustainability. In contrast, training, mixed technology adoption, distance to the dumpsite, and contract duration have negative and statistically significant effects. Mixed collection methods and the mixed nature of areas served have no statistically significant effects. The study concludes that both firm-specific and external operating factors influence the financial sustainability of private SWM firms, although their effects vary. Accordingly, municipal authorities should review service-contract arrangements and facilitate operating conditions that support financially sustainable waste collection. Firm owners and managers should strengthen customer management, adopt appropriate technology, and optimise waste-collection frequency schedules.

Keywords: Financial Sustainability; Financial Self-Sufficiency, Private Firms; System GMM; Solid Waste Management

I. INTRODUCTION

Financial sustainability remains a critical challenge for firms delivering essential public services in developing countries (Ezeudu & Bristow, 2025). Increasing municipal solid waste volumes have substantially increased waste collection costs, placing considerable pressure on the financial sustainability of private solid waste management (SWM) firms. This situation highlights the need for sustainable SWM practices, as inadequate responses to increasing waste volumes may intensify environmental pollution and financial pressures on service providers (Hoang & Fogarassy, 2020). Maintaining consistent service delivery and financial sustainability also requires adequate investment in infrastructure and appropriate technologies (Ozili & Iorember, 2024). From the perspective of Contingency Theory, organisational performance varies according to internal organisational characteristics and external operating conditions. Applied to private SWM firms, this suggests that financial sustainability may be associated with both firm-specific and external operating factors. Therefore, understanding these determinants is important for strengthening the financial sustainability and continuity of private SWM firms' service provision.

The increasing reliance on private firms to deliver municipal solid waste management (MSWM) services has shifted attention from service provision alone to firms' financial capacity to sustain service delivery over time (Biswas & Singh, 2021; Bartolacci et al., 2018). However, sustaining these services remains challenging for many private SWM firms, as rising operational costs and inadequate revenue generation constrain their ability to remain financially sustainable (Mpuya & Munishi, 2024). These financial constraints are particularly pronounced in developing countries, where weak institutional support, limited access to finance, and rapidly growing urban populations create additional financial pressures on private SWM firms (Ezeudu & Bristow, 2025; Otundo, 2024; Lissah et al., 2021; Noufal et al., 2020). Developed countries, by contrast, have increasingly adopted strategies

emphasising circular economy models, eco-efficiency, and waste diversion (Moshkal et al., 2024; Abdeljaber et al., 2022; Hemidat et al., 2022). Even within well-developed waste management systems, private SWM companies in developed countries remain vulnerable to rising operational costs, volatile revenue streams, and increasingly stringent environmental regulations, which continue to threaten their financial sustainability (Itván Szűcs & Gáthy, 2024; Mim et al., 2025; Gradus et al., 2019). Thus, although operating conditions differ between developing and developed countries, maintaining financial sustainability remains a key concern for private SWM firms across these contexts.

Tanzania is no exception to these challenges, although the government has taken measures to strengthen private-sector participation in SWM. These efforts have been supported by legal, policy, and institutional frameworks, including the Environmental (Solid Waste Management) Regulations of 2009, which support private-sector participation by providing for the licensing of private waste collection operators and municipal oversight of SWM services, the Environmental Management Act of 2004, which provides for private-sector involvement in waste management; the National Environmental Policy of 2021, which encourages private-sector investment and collaboration in environmental management; and the National Solid Waste Management Strategy of 2018, which promotes sustainable and coordinated SWM practices (EMR 2009; EMA, 2004; URT, 2021; URT, 2018). Moreover, at the local government level, municipalities have introduced by-laws and enforcement measures, including fines and restrictions on access to selected municipal services for non-compliant service users, to strengthen compliance with waste collection services, particularly the payment of refuse collection fees (Harfadli et al., 2024; Biswas & Singh, 2021; Kirama & Mayo, 2016). Nevertheless, these efforts have not fully addressed the financial challenges facing private SWM firms, as cost-recovery difficulties and rising operational costs continue to constrain their financial sustainability.

Existing empirical studies on SWM have primarily examined waste financing and cost-recovery mechanisms (Ezeudu & Bristow, 2025), circular economy approaches (Sondh et al., 2024), and broader assessments of municipal solid waste management systems (Ceraso & Cesaro, 2024). Only a few studies have explicitly examined the financial sustainability of waste management firms (Mim et al., 2025; Bartolacci et al., 2018). In Tanzania, studies on SWM have mainly examined private sector participation, operational challenges, and private-sector performance in SWM (Mpuya & Munishi, 2024; Kirama & Mayo, 2016). Although studies from other sectors have investigated the determinants of financial sustainability (Marwa et al., 2026; Rwekaza et al., 2025; Njiku & Nyamsogoro, 2019), comparable evidence from the private SWM sector remains limited. Consequently, empirical evidence on the firm-specific and external operating determinants of financial sustainability among private SWM firms in Tanzania remains limited. Furthermore, existing studies provide limited longitudinal analysis of how the financial sustainability of private SWM firms evolves. This study addresses these empirical, contextual, and methodological gaps by applying the Two-Step System GMM estimator to examine the determinants of financial sustainability among private SWM firms in Dar es Salaam, Tanzania, while accounting for the persistence of financial sustainability and potential endogeneity. Njiku & Nyamsogoro, 2019

The findings are expected to help private SWM firms identify factors to improve financial sustainability, while providing local government authorities with evidence to strengthen the operating environment for sustainable private SWM service provision. The study also contributes to Sustainable Development Goal 11 on sustainable cities and communities and Tanzania Development Vision 2050, which emphasises improved quality of life and sustainable living environments.

1.2 Research Objective

This study examines the determinants of financial sustainability among private SWM firms in Dar es Salaam, Tanzania.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.2 Contingency Theory

Contingency Theory (CT) as discussed by Donaldson (2001). It suggests that no single organisational approach suits all firms because organisational performance depends on the circumstances under which firms operate. The theory emphasises that organisational outcomes are influenced by internal organisational characteristics and external operating conditions. Accordingly, differences in these factors may explain variations in firm performance (Purnamasari & Adriza, 2024). In this study, CT provides a theoretical basis for explaining how firm-specific and external operating factors influence the financial sustainability of private solid waste management (SWM) firms in Dar es Salaam. Firm-specific factors, including firm age and technology adoption, may influence operational capacity and costs, while external operating factors, such as collection methods and collection frequency, may affect revenue

generation and operating expenses. Consequently, differences in these factors may explain variations in financial sustainability among private SWM firms. This highlights the importance of considering both firm-specific characteristics and external operating conditions when examining differences in financial sustainability. The theory therefore offers a useful perspective for understanding why firms operating within the same industry may experience different financial outcomes. However, Contingency Theory has been criticised for offering limited guidance on which organisational characteristics and external operating conditions best explain firm performance. Despite this limitation, the theory remains relevant to this study because it provides a framework for examining how firm-specific and external operating factors influence the financial sustainability of private SWM firms.

2.2 Empirical Review

Studies on financial sustainability across various sectors have drawn considerable interest in recent years. Within this broader discourse, the present study focuses on firm-specific and external operating factors that may influence the financial sustainability of SWM service providers. In this study, financial sustainability refers to a firm's capacity to generate sufficient revenue to meet operating expenses and sustain operations through internally generated revenue.

Firm-specific factors represent internal characteristics that may shape organisational performance and financial sustainability. Empirical evidence has examined how these characteristics influence financial sustainability and related financial outcomes across sectors. Fadilah et al. (2022) and Mallingu et al. (2020), using multiple linear regression and structural equation modelling (SEM), found a positive effect of firm age on sustainability and financial performance respectively, whereas Felipe et al. (2021), using a fixed-effects model, found that firm age negatively affected profitability. These mixed findings suggest that firm age affects financial and sustainability outcomes differently. Firm size has also been associated with financial outcomes. Fonseca et al. (2022) found that firm size, measured by the number of employees, was positively associated with profitability. Conversely, Njiku and Nyamsogoro (2019), using hierarchical multiple regression, established a significant negative relationship between firm size and financial sustainability. These contrasting findings suggest that the influence of firm size on financial sustainability may vary across organisational and operational contexts.

Njiku and Nyamsogoro (2019), using hierarchical multiple regression, found that employee training significantly influenced financial sustainability. In contrast, Okonye and Nwamerenini (2025), using secondary data and OLS multiple regression, found that staff training and development costs had a negative and significant effect on profit after tax and return on assets. These studies were conducted outside the SWM sector, leaving limited evidence on whether training similarly influences the financial sustainability of private SWM firms. Technology adoption may also affect the financial performance of waste collection. Taube et al. (2022) found that integrating electric waste-collection vehicles with waste-management plants could reduce operating costs, while Erdem and Özdemir (2025), using a fuzzy mixed-fleet model of conventional-fuel and electric waste-collection vehicles, showed that fleet composition and cost factors influence operating expenses. The mixed findings and limited evidence from private SWM firms highlight the need to examine further the relationship between firm-specific factors and financial sustainability. Accordingly, the following hypotheses are proposed:

Hypotheses: Firm age (H1), firm size (H2), training (H3), new technology adoption (H4a), and mixed technology adoption (H4b) each significantly influence financial sustainability.

Beyond firm-specific attributes, external operating factors may also influence financial sustainability. External operating factors refer to conditions related to the environment and arrangements under which firms deliver their services, which may influence their financial sustainability. The number of customers served may affect firms' revenue-generating capacity and, consequently, their financial sustainability. Lohri et al. (2014), using a cost-revenue analysis of a private waste collection company in Ethiopia, found that waste collection fees constituted the main revenue source, although low fee collection rates undermined financial sustainability. This finding suggests that the financial contribution of customers served may depend on how effectively the company collects fees. Jin et al. (2022), using panel analysis, found that customer concentration was associated with corporate performance. This evidence suggests that the number of customers served may have important implications for the financial sustainability of private SWM firms.

The choice of waste collection method is another factor potentially associated with the financial sustainability of waste collection services. Hess et al. (2024), Laurieri et al. (2020) and Carlos et al. (2019), using a literature review, case-study survey, and comparative case-study approach, respectively, found that different waste collection methods influence operational efficiency and may consequently affect collection costs and sustainability. Bø and Flygansvør (2025), using comparative modelling, found that shared-bin collection arrangements could reduce waste collection costs, suggesting that certain forms of container-based collection may contribute to improved financial sustainability. However, existing studies have primarily examined collection efficiency, costs, and environmental

performance, providing limited direct evidence on how different collection methods influence the financial sustainability of private SWM firms.

Contract duration may influence firms' financial sustainability by affecting investment and operational stability. Hartman et al. (2020), using a qualitative multiple-case study, found that longer-term contracts reduced contract-specific risks and facilitated supplier investment. Similarly, Liem and Khuong (2020), using panel data from manufacturing firms, found that longer-term buyer–supplier contracts were positively associated with firms' propensity to innovate. These findings suggest that contract duration may affect firms' investment and operating conditions and, consequently, their financial sustainability.

Waste collection frequency has important financial implications for SWM service provision, because customers may place greater value on more frequent services. Rai et al. (2019), using a choice experiment, found that households were willing to pay more for more frequent waste collection. Similarly, Tarfasa and Brouwer (2018), using a discrete-choice experiment and mixed-logit analysis in Ethiopia, found substantial willingness to pay for more frequent collection. These findings suggest that more frequent collection may increase revenue by leveraging customers' willingness to pay for improved waste collection services, thereby supporting SWM firms' financial sustainability.

Distance to the dumpsite is an important operational consideration because transportation contributes to waste collection costs. Sulemana et al. (2019), using a paired test, found that optimal routing reduced travel distance, travel time, fuel consumption, and waste collection operating costs. Kinobe et al. (2015), using a case study and GIS-based route optimisation, similarly found that optimising collection routes reduced travel distance, fuel consumption, and waste collection costs. These findings suggest that longer distances to disposal facilities may increase transportation and operating costs, with potential implications for financial sustainability.

The nature of the service area is another factor shaping the operating conditions of waste collection firms. Owusu-Ansah et al. (2021), using a household survey and statistical analysis, found that poor spatial planning and inadequate access roads hindered effective waste management service delivery. Similarly, Guo (2025), using a mixed-methods approach, found that integrating waste management into urban planning and providing adequate infrastructure improved waste management efficiency and reduced associated costs. These findings suggest that service-area characteristics may affect SWM service providers' costs.

Although substantial evidence exists in waste management and other sectors, empirical findings on how external operating factors affect the financial sustainability of private SWM firms remain limited. This gap is important because the sector's unique operating conditions may influence financial sustainability differently from those in other industries. Consequently, the following hypotheses are developed:

Hypotheses: Container-based collection (H5a), mixed collection methods (H5b), planned service areas (H6a), mixed service areas (H6b), distance to the dumpsite (H7), contract duration (H8), customers served (H9), and waste collection frequency (H10) each significantly influence financial sustainability.

III. METHODOLOGY

3.1 Study Philosophy, Design and Approach

The study follows a positivist research philosophy, which emphasises objective measurement and statistical analysis of observable phenomena. Accordingly, the study adopted a quantitative research approach to measure the variables numerically, test their relationships, and draw empirical conclusions. A longitudinal panel research design was employed to capture variations across private SWM firms and changes over time, making it appropriate for examining the determinants of financial sustainability using dynamic panel estimation techniques.

3.2 Area of Study

Dar es Salaam was selected as the study area because it generates the largest volume of municipal solid waste in Tanzania, estimated at 4,161 tonnes daily, posing immense challenges in waste collection (Biswas & Singh, 2021). The city also has substantial private firms' participation in SWM, reflecting a growing shift from centralised Municipal provision to decentralisation (Kasala, 2014). These aspects make Dar es Salaam a suitable area, both for its operational relevance in waste service delivery and for the practical access to data for the study.

3.3 Sampling and Data Collection

A census approach was employed to identify all private SWM firms operating in Dar es Salaam during the 2016–2023 study period. This approach was appropriate given the relatively small population of private SWM service providers in the city. The year 2016 was selected as the base year following the administrative reorganisation that established Kigamboni and Ubungu Municipalities, which altered the institutional structure of SWM service

administration in Dar es Salaam. A total of 40 private SWM firms were identified from the records of municipal SWM departments. Firms were eligible for inclusion if they had operated for at least three years during the study period and had sufficient financial and operational records for constructing the study variables. The minimum observation period was intended to ensure adequate longitudinal information and permit the use of lagged variables in the dynamic panel estimation. Of the 40 firms identified, 36 met these eligibility requirements and were retained for analysis. Of the four excluded firms, two had operated for less than six months because they were newly established, while two had insufficient information on key study variables. The resulting panel structure ($N = 36$, $T \leq 8$) was suitable for System GMM estimation (Ally et al., 2025).

Data were extracted from firms' human resource records, operational records, and audited financial statements. Differences in firms' entry, exit, contractual arrangements, and record availability resulted in varying numbers of annual observations across firms. Consequently, an unbalanced panel was constructed using all available eligible firm-year observations rather than restricting the analysis to firms observed throughout the entire study period. This approach allowed firms with different periods of operation to contribute available observations and reduced potential information loss that would arise from requiring a balanced panel. The study also acknowledges the potential effects of the COVID-19 period. However, SWM remained an essential municipal service in Tanzania, with measures implemented to facilitate service continuity during the pandemic (Aikaeli et al., 2021; TURP, 2020).

3.4 Measurement and operationalisation of research variables.

Table 1 presents the study variables, their measurements, initial signs, expected signs, descriptions, and references.

Table 1

Operationalisation of key research variables

Variable	Definition And Measurement	Initials	Reference
Firm-specific factors			
Firm Size	Measured by the number of employees.	SIZE	Njiku and Nyamsogoro (2019)
Technology adopted	Categorical variable: 2 = New technology adopted, 3 = Mixed technology adopted 1=Old (Reference group)	TECH	(Abdinazar & Hairong, 2025; Singh et al., 2024)
Training	Measured by the number of training sessions conducted per annum.	TRAIN	(Khan & Abdullah, 2019)
Firm Age	Measured by the number of years since its establishment.	AGE	(Lyimo & Walter, 2023; Bogetić & Olusi, 2013)
External operating factors			
Customers served	Measured by the number of customers served annually.	CUSTO_SERV	(Jin et al., 2022; Lohri et al., 2014)
Distance to the dumpsite	Measured by total kilometres travelled to the dumpsite during the year.	DIST_LF	(Kinobe et al., 2015)
Method of waste collection	Categorical variable: 2 = Container collection method, 3 = Mixed collection method 1= Door to Door (Reference group)	COLL_METH	(Baltrocchi et al., 2024)
Waste collection frequency	Measured by the total number of trips undertaken annually.	FREQ	(Kosoe et al., 2025; Chamwali et al., 2022)
Nature of area served	Categorical variable: 2 = Planned nature of area served 3 = Mixed nature of area served 1=Unplanned (Reference group)	NATU_AREA	(Owusu-Ansah et al., 2021)
Contract duration	Measured by the number of years specified in the applicable service contract.	CONT_DUR	(Lim & Mali, 2023)
Dependent variable			
Financial sustainability	Measured using the FSS ratio (revenue/expenses)	FS	(Zhao et al., 2022; Marwa & Aziakpono, 2015)

3.5 Measurement of Financial Sustainability Using Financial Self-Sufficiency

In this study, financial sustainability (FS) refers to SWM firms' ability to generate sufficient revenue from service provision to cover operating expenses, generate an operating surplus, and maintain service provision over time without persistent dependence on external financial support. This definition emphasises firms' capacity to finance their waste collection activities through revenue generated from their services. Consistent with previous studies that have used Financial Self-Sufficiency (FSS) to measure financial sustainability (Yasmin et al., 2024; Maeenuddin et al., 2024; Njiku & Nyamsogoro, 2019; Marwa & Aziakpono, 2015). This study operationalised financial sustainability using the FSS ratio. The selection of FSS was guided by the study's objective of assessing private solid waste management firms' ability to finance their operating activities through internally generated revenue, the availability of consistent firm-level financial records, and its established application in previous research. The FSS ratio was calculated using unadjusted revenue from waste collection fees divided by unadjusted operating expenses associated with waste collection services. The firms generated revenue solely from waste collection fees and received no

subsidies or other external financial support. Unadjusted financial figures were appropriate given the predominantly cash-based nature of the firms' transactions, consistent with the approach adopted by Njiku and Nyamsogoro (2019). The ratio was calculated as follows:

$$FSS_{it} = \text{Revenue}_{it} / \text{Expenses}_{it}$$

Where:

FSS_{it} denotes financial self-sufficiency of firm i in year t ; Revenue_{it} represents revenue collected from waste collection fees; and $\text{Operating Expenses}_{it}$ comprises the expenses associated with providing waste collection services, including fuel, vehicle maintenance, and other relevant service-delivery costs. FSS ratio greater than 1 denotes financial sustainability, while a ratio below 1 denotes financial unsustainability.

3.6 Model Specification

To analyse the determinants of financial sustainability among private SWM firms in Dar es Salaam, the study employed the two-step System Generalised Method of Moments (System GMM) estimator using STATA version 17. System GMM was appropriate for the dynamic panel of 36 firms observed over 2016–2023, as it allows the inclusion of a lagged dependent variable to capture persistence in financial sustainability. The estimator accounts for unobserved time-invariant firm-specific heterogeneity through transformation and addresses potential endogeneity arising from simultaneity and reverse causality using internal instruments (Blundell & Bond, 1998; Arellano & Bover, 1995).

Financial sustainability, measured using the FSS ratio, was specified as the dependent variable, while firm-specific and external operating factors were included as explanatory variables. Continuous variables were transformed using natural logarithms where appropriate, while categorical variables were represented by dummy variables with clearly defined reference categories. The lagged value of FSS was included to capture persistence in financial sustainability, recognising that firms' current financial positions may partly depend on their previous financial positions.

The lagged dependent variable and regressors treated as endogenous or predetermined were instrumented using appropriate lagged levels in the differenced equation and lagged differences in the level equation, while strictly exogenous regressors were included as standard instruments. To mitigate instrument proliferation, the instrument matrix was collapsed and the lag depth restricted, maintaining the number of instruments below the number of cross-sectional units (Roodman, 2009). Model adequacy was assessed using the Arellano–Bond tests for first- and second-order serial correlation, AR (1) and AR (2), while the Hansen and Sargan tests of overidentifying restrictions were used to assess instrument validity.

For benchmarking purposes, Pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and two-step Difference GMM estimates were also reported. OLS and FE were used only as benchmarks because they do not adequately address endogeneity concerns in dynamic panel models with a lagged dependent variable and potentially endogenous regressors (Mmbaga et al., 2023). Difference GMM was included as an alternative dynamic panel estimator to assess the robustness of the System GMM results. System GMM was therefore retained as the preferred estimator for statistical inference. Accordingly, FSS was used as the dependent variable to estimate the firm-specific and external operating determinants of financial sustainability. The dynamic panel model was specified as follows:

$$FSS_{it} = \beta_0 + \beta_1 FSS_{it-1} + \beta_2 AGE_{it} + \beta_3 SIZE_{it} + \beta_4 TRAIN_{it} + \beta_5 NEW_TECH_{it} + \beta_6 MIXED_TECH_{it} + \beta_7 CONT_METH_{it} + \beta_8 MIXED_METH_{it} + \beta_9 PLAN_AREA_{it} + \beta_{10} MIXED_AREA_{it} + \beta_{11} DIST_LF_{it} + \beta_{12} CONT_DUR_{it} + \beta_{13} CUSTO_SERV_{it} + \beta_{14} FREQ_{it} + \varepsilon_{it}$$

Where: All variables are as described in Table 1, and ε_{it} is the error term.

3.7 Diagnostic Tests

The following diagnostic tests were conducted to assess the characteristics of the panel data and evaluate the validity of the estimated models.

3.7.1 Pairwise Correlations Matrix and Variance Inflation Factor

Table 2 presents the pairwise correlation coefficients and variance inflation factor (VIF) results used to assess potential multicollinearity among the study variables. The correlation coefficients among the explanatory variables were generally below the commonly applied threshold of 0.80, with the highest correlation observed between distance to the dumpsite and waste collection frequency ($r = 0.734$), followed by firm size and mixed technology adoption ($r = 0.719$). The VIF values ranged from 1.14 to 4.79, with a mean of 2.38, indicating no severe multicollinearity among

the explanatory variables. These results suggest that multicollinearity is unlikely to pose a substantial concern for the regression analysis.

Table 2

Pairwise correlation matrix and Variance Inflation Factor

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) FinancialSS	1.000													
(2) Firm age	0.060	1.000												
(3) Firm_size	0.002	0.197 ^a	1.000											
(4) Training	-0.012	-0.038	0.169 ^b	1.000										
(5) New_technolo adopted~2	-0.118 ^c	0.052	-0.025	0.115 ^c	1.000									
(6) Mixed_technolo adopted~3	0.024	0.097	0.719 ^a	0.232 ^a	-0.120 ^c	1.000								
(7) Container method of waste collection~2	-0.028	0.085	0.175 ^a	0.035	-0.048	0.396 ^a	1.000							
(8) Mixed method of collect~3	0.013	0.100	0.098	0.392 ^a	-0.044	0.305 ^a	-0.033	1.000						
(9) Planned nature of area_2	-0.106	0.129 ^b	0.053	-0.022	0.595 ^a	0.089	0.383 ^a	-0.041	1.000					
(10) Mixed nature of area_3	0.044	-0.087	0.507 ^a	0.292 ^a	0.044	0.592 ^a	0.093	0.283 ^a	-0.145 ^b	1.000				
(11) ln_distance_to dumpsite	0.057	0.034	0.411 ^a	0.166 ^b	0.161 ^b	0.327 ^a	0.097	0.038	0.069	0.457 ^a	1.000			
(12) Contract duration	0.031	-0.009	0.162 ^b	0.171 ^a	0.063	0.059	-0.054	-0.032	-0.087	0.177 ^a	0.216 ^a	1.000		
(13) ln_customers served	0.023	0.456 ^a	0.497 ^a	0.185 ^a	0.146 ^b	0.445 ^a	0.198 ^a	0.290 ^a	0.228 ^a	0.216 ^a	0.257 ^a	0.028	1.000	
(14) ln_Waste collection frequency_~n	0.047	0.201 ^a	0.368 ^a	0.091	0.078	0.307 ^a	0.167 ^b	0.141 ^b	0.112 ^c	0.321 ^a	0.734 ^a	0.084	0.355 ^a	1.000
VIF		1.41	2.80	1.35	2.28	3.56	1.69	1.62	2.56	2.33	3.42	1.14	1.93	4.79
1/VIF		0.708	0.358	0.740	0.438	0.281	0.590	0.616	0.391	0.429	0.293	0.876	0.517	0.209
Mean VIF														2.38

Source Note: Significance level: ^a $p < 0.01$, ^b $p < 0.05$, ^c $p < 0.1$

3.7.2 Panel Unit Root for Stationarity

Table 3 presents the results of the Fisher-type panel unit root test conducted to determine the stationarity and order of integration of the study variables before model estimation. Table 3 shows that FinancialSS, training, and ln customers served were stationary at level $I(0)$, while the remaining variables became stationary after first differencing, $I(1)$. Thus, none of the variables was integrated of order two, $I(2)$. Categorical variables, namely technology adoption, collection method, and nature of service area, were excluded from the panel unit-root analysis because their numerical codes represent discrete categories rather than continuous stochastic processes for which conventional panel unit-root tests are appropriate. These variables were therefore incorporated directly into the regression models as categorical variables using dummy indicators.

Table 3*Fisher-type unit-root test*

Variables	Level constant and trend				First difference Constant trend				Order of
	Inverse chi-squared(72)	Inverse normal	Inverse logit	Modified inv. chi-	Inverse chi-	Inverse normal	Inverse logit	Modified inv.	
FinancialSS	437.806***	-12.955***	-19.787***	30.484***					I (0)
Firm age	4.1982	2.2598	2.3247	-5.6502	71.0392	-6.1051***	-8.0245***	0.0878	I (1)
Firm size	15.274	4.920	4.741	-4.727	126.222***	-5.148***	-5.330***	4.752***	I (1)
Training	112.716**	-1.946**	-4.618***	3.393**					I (0)
Ln distance to the dumpsite	64.491	0.286	-0.945	-0.626	107.918**	-4.733***	-5.922***	3.205***	I (1)
Contract duration	8.0069	4.02	3.727	-5.3328	67.550	-4.102***	-3.802***	-0.207	I (1)
Ln customers served	235.921***	-3.690***	-7.313***	13.660***					I (0)
Ln waste collection frequency	23.156	0.994	0.773	-4.070	78.794	-4.558***	-5.091***	0.743	I (1)

Source Note: Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.9.5 Arellano-Bond and Hansen and Sargan Test

Table 5 presents the post-estimation diagnostic tests used to assess serial correlation and instrument validity in the System GMM model. The Arellano–Bond test indicates significant first-order serial correlation, AR(1) ($p = 0.023$), but no statistically significant second-order serial correlation, AR(2) ($p = 0.597$), consistent with the requirements for a valid dynamic panel specification. The Hansen ($p = 0.684$) and Sargan ($p = 0.986$) tests fail to reject the null hypothesis of instrument validity, providing no evidence against instrument validity. Furthermore, the model uses 32 instruments for 36 firms, keeping the instrument count below the number of cross-sectional units and reducing concerns about instrument proliferation. These diagnostic results support the adequacy of the System GMM specification for statistical inference.

IV. FINDINGS & DISCUSSION

4.1 Descriptive Statistics

Table 4a presents descriptive statistics for continuous variables, highlighting key preliminary insights into the data used in this study. FS has a mean of 0.894 with low variation, indicating that most firms operate below the financial sustainability threshold, with only a few performing better financially. Firm-specific factors, firm size ($\bar{x} = 48.361$, $SD = 49.824$), and training ($\bar{x} = 1.558$, $SD = 2.387$) show substantial dispersion, indicating differences in workforce size and staff training, respectively, across firms. Firm age ($\bar{x} = 5.455$, $SD = 3.716$) suggests heterogeneity in firms' operational maturity. In addition, external factors show that the contract duration ($\bar{x} = 2.039$, $SD = 1.001$) indicates that most firms operate under medium-length contracts. Ln of distance to dumpsite ($\bar{x} = 9.056$, $SD = 0.448$); Ln of customers served ($\bar{x} = 7.958$, $SD = 0.694$). Ln of collection frequency ($\bar{x} = 5.579$, $SD = 0.348$) indicates variation across firms, with relatively higher dispersion in the number of customers served than in distance to the dumpsite and collection frequency.

Table 4b summarises the distribution of the categorical variables. Old technology accounted for most observations (75.54%), followed by mixed technology (18.45%) and new technology (6.01%). Door-to-door collection was the most common method (93.56%), with container and mixed methods accounting for only small proportions. In terms of nature of service areas, most observations were from unplanned areas (66.95%), followed by mixed areas (27.90%), while planned areas accounted for 5.15%.

Table 4a
Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FSS	233	0.894	0.12	0.53	1.17
Firm age	233	5.455	3.716	1	19
Firm size	233	48.361	49.824	10	337
Training	233	1.558	2.387	0	12
Contract duration	233	2.039	1.001	1	3
ln distance to the dumpsite	233	9.056	0.448	7.763	9.688
ln customers served	233	7.958	0.694	6.109	9.324
ln waste collection frequency	233	5.579	0.348	4.564	5.9

Table 4b:
Descriptive Statistics for Categorical Variables

Variable	Category	Frequency (n)	Percentage (%)
Technology adopted	Old technology adopted (1)	176	75.54
	New technology adopted (2)	14	6.01
	Mixed technology adopted (3)	43	18.45
	Total	233	100.00
Method of waste collection	Door-to-door method (1)	218	93.56
	Container collection method (2)	8	3.43
	Mixed collection method (3)	7	3.00
	Total	233	100.00
Nature of area served	Unplanned nature of area served (1)	156	66.95
	Planned nature of area served (2)	12	5.15
	Mixed nature of area served (3)	65	27.90
	Total	233	100.00

4.2 System GMM results

4.2.1 Firm-Specific Factors and External Operating Determinants of Financial Sustainability

Table 5 presents the dynamic panel regression results based on the two-step System GMM estimator for the determinants of financial sustainability among private SWM firms. The lagged financial sustainability coefficient is positive and statistically significant ($\beta = 0.572$, $p < 0.01$), indicating persistence in firms' financial sustainability. Thus, firms with higher financial sustainability in the preceding period tend to maintain higher financial sustainability in the current period. This finding is consistent with Boonyanet et al. (2024), who similarly reported a significant dynamic effect of the lagged dependent variable. The result highlights the importance of maintaining financial stability consistently rather than relying on short-term improvements.

Regarding firm-specific factors, firm age has a positive and statistically significant effect on financial sustainability ($\beta = 0.045$, $p < 0.01$), supporting H1. The positive relationship indicates that older private SWM firms tend to exhibit higher financial sustainability than younger firms, holding other factors constant. The finding is consistent with Fadilah et al. (2022) and Mallingu et al. (2020), who found significant relationships between firm age and sustainability-related and financial performance, respectively. This association may reflect accumulated operating experience and established customer relationships, which may enhance the financial sustainability of private SWM firms.

Similarly, firm size positively and significantly affects financial sustainability ($\beta = 0.003$, $p < 0.10$), supporting H2. This finding suggests that greater workforce capacity is associated with higher financial sustainability among private SWM firms. The finding is consistent with Fonseca et al. (2022), who found that firm size, measured by the number of employees, was positively associated with profitability. Both profitability and financial sustainability reflect aspects of financial performance; thus, their finding provides relevant evidence supporting the relationship between firm size and financial sustainability. Furthermore, training has a negative and statistically significant effect on financial sustainability ($\beta = -0.030$, $p < 0.05$), which does not support H3. This negative relationship implies that greater training activity does not necessarily translate into higher financial sustainability among private SWM firms. The finding is consistent with Okonye and Nwamerenini (2025), who found that staff training and development costs had negative and significant effects on profit after tax and return on assets. Besides, although training may be associated with improved performance, the current findings suggest that this is not always the case, as training may also be associated with lower financial sustainability. Technology adoption produces mixed results. Compared with firms using old technology, firms adopting new technology show significantly higher financial sustainability ($\beta = 4.818$, $p < 0.05$), supporting H4a, whereas mixed technology has a negative but statistically significant effect ($\beta =$

-0.149, $p < 0.05$), not supporting H4b. These results indicate that the financial implications of technology adoption vary by technology type. This finding on new technology is consistent with Taube et al. (2022), who found that integrating electric waste-collection vehicles with waste-management plants could reduce operating costs. Erdem and Özdemir (2025) further showed that mixed vehicle fleets have cost implications that depend on fleet composition and operating conditions. Accordingly, adopting new technology may be more favourable to financial sustainability than combining old and new technologies.

Regarding waste collection methods, firms using container-based collection show a significantly greater influence on financial sustainability than those using door-to-door collection, the reference category ($\beta = 1.014$, $p < 0.10$), supporting H5a. In contrast, mixed collection methods show no statistically significant difference from door-to-door collection ($\beta = -0.238$, $p > 0.10$), which does not support H5b. The finding on container-based collection is consistent with Bø & Flygansvør (2025), who found that shared household container systems can reduce collection costs. However, Pietro et al. (2024) reported advantages of fully door-to-door systems in operational effectiveness, indicating that collection performance may vary across operating environments. In the present study, container-based collection may provide financial advantages over door-to-door collection, whereas mixed collection methods do not necessarily improve financial sustainability.

The nature of the service area also produces mixed results. Compared with firms operating in unplanned areas, firms serving planned areas exhibit significantly higher financial sustainability ($\beta = 2.264$, $p < 0.05$), supporting H6a. In contrast, serving mixed areas has no statistically significant effect on financial sustainability ($\beta = -0.189$, $p > 0.10$), which does not support H6b. The finding for planned areas is consistent with Owusu-Ansah et al. (2021), who found that poor spatial planning and inadequate road accessibility constrain effective solid waste service delivery. Thus, the positive result for planned areas may reflect operational advantages associated with better accessibility and easier movement of collection vehicles. Hence, service-area characteristics may have important implications for the financial sustainability of private SWM firms.

Distance to the dumpsite is negatively and statistically significantly associated with financial sustainability ($\beta = -1.994$, $p < 0.05$), which does not support H7. The negative relationship suggests that greater distance to the disposal site is associated with lower financial sustainability. The finding is consistent with Sulemana et al. (2019), who found that reducing travel distance lowered fuel consumption and waste collection operating costs. Similarly, Kinobe et al. (2015) found that route optimisation reduced travel distance, fuel consumption, and collection costs. Consequently, longer travel distances to the dumpsite may increase operating costs and, consequently, reduce the financial sustainability of private SWM firms.

Contract duration has a negative and statistically significant effect on financial sustainability ($\beta = -0.036$, $p < 0.05$), which does not support H8. This result implies that longer contract duration is associated with lower financial sustainability among the sampled firms. In contrast, Hartman et al. (2020) found that longer-term contracts reduced contract-specific risks and facilitated supplier investment, while Liem and Khuong (2020) linked longer contractual relationships with greater investment in innovation. The negative relationship found in the present study therefore suggests that longer contracts do not necessarily translate into greater financial sustainability. The result highlights the importance of appropriate contract duration and flexible contractual arrangements under changing operating conditions.

The number of customers served positively and significantly influences financial sustainability ($\beta = 0.187$, $p < 0.05$), supporting H9. This finding suggests that firms serving larger customer bases tend to exhibit higher financial sustainability. This finding is consistent with Lohri et al. (2014), who highlighted customer fees as a major revenue source in private waste service provision, and Jin et al. (2022), who linked customer concentration to corporate performance. Thus, serving more customers may broaden the revenue base and support the financial sustainability of private SWM firms, provided they collect fees effectively.

Waste collection frequency has a positive and statistically significant effect on financial sustainability ($\beta = 3.000$, $p < 0.05$), supporting H10. The positive relationship indicates that higher waste collection frequency is associated with higher financial sustainability among private SWM firms. The finding is consistent with Rai et al. (2019) and Tarfasa and Brouwer (2018), who found that increased waste collection frequency was associated with greater willingness to pay for waste collection services. These results suggest that increased waste collection frequency may support revenue generation and, consequently, the financial sustainability of SWM service providers.

The findings indicate that private SWM firms' financial sustainability is influenced by both firm-specific characteristics and the external operating conditions under which they provide services.

Table 5*Panel regression results*

	(1)	(2)	(3)	(4)
VARIABLES	Pooled OLS	FE	2Step Diff GMM	2Step Syst GMM
L.FinancialSS	0.883*** (0.258)	0.211*** (0.078)	0.233*** (0.085)	0.572*** (0.158)
Firm age	-0.003 (0.003)	-0.009 (0.007)	0.029*** (0.005)	0.045*** (0.017)
Firm size	-0.000 (0.000)	0.000 (0.001)	-0.001 (0.001)	0.003* (0.002)
Training	-0.004 (0.004)	-0.006 (0.007)	-0.023*** (0.008)	-0.030** (0.014)
2. New technology adopted	-0.019 (0.055)			4.818** (1.927)
3. Mixed technology adopted	0.047 (0.036)	-0.006 (0.054)	-0.095** (0.045)	-0.149** (0.062)
2.Container_collection method	-0.028 (0.053)			1.014* (0.519)
3.Mixed_collection method	0.011 (0.057)	-0.148 (0.124)	-0.087 (0.161)	-0.238 (0.153)
2. Planned nature of area served	-0.070 (0.059)	-0.122 (0.135)	-0.068 (0.224)	2.264** (1.151)
3.Mixed_nature of area served	-0.007 (0.026)	-0.067 (0.108)	-0.200 (0.171)	-0.189 (0.268)
Contract duration	-0.009 (0.008)	-0.000 (0.015)	0.036** (0.030)	-0.036** (0.017)
Ln distance to the dumpsite	0.032 (0.040)	0.043 (0.188)	1.547*** (0.466)	-1.994** (0.852)
Ln_customers served	0.003 (0.016)	-0.022 (0.030)	0.058 (0.053)	0.187** (0.073)
Ln waste collection frequency	-0.032 (0.050)	0.047 (0.198)	-0.616 (0.472)	3.000** (1.165)
Constant	1.000*** (0.214)	0.724 (0.760)		4.319 (4.953)
Observations	197	197	161	197
R-squared	0.103	0.124		
Number of firms		36	36	36
AR(1)			0.023	0.023
AR(2)			0.818	0.597
Hansen			0.792	0.684
Sargan			0.559	0.986
Number of Instruments			32.000	32.000

Source Note: Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study investigated the firm-specific and external operating factors influencing the financial sustainability of private solid waste management firms in Dar es Salaam, Tanzania. Using longitudinal panel data and a dynamic System GMM approach, the study finds that multiple factors shape financial sustainability, with directions and statistical significance varying. Firm age, firm size, new technology adoption, container-based collection, operation in planned areas, customers served, and collection frequency contribute positively to financial sustainability, while training, distance to the dumpsite, mixed technology adoption and contract duration have negative effects. Mixed collection methods and the mixed nature of the service area do not significantly influence financial sustainability. The significant lagged effect on financial sustainability further shows persistence in firms' financial conditions, suggesting



that current financial sustainability is partly shaped by previous financial performance. The study therefore concludes that achieving financial sustainability among private SWM firms depends on both firm-specific factors and external operating factors associated with waste collection service provision.

5.2 Recommendations

Firm owners and managers should prioritise investment in appropriate modern waste collection technologies that improve service reliability while remaining affordable to operate and maintain. They should introduce such investments progressively, based on firms' financial capacity and operational requirements. Given the positive effect on the number of customers served, firm owners and managers should strengthen customer acquisition and retention by improving service reliability, maintaining accurate customer records, and responding promptly to customer service concerns within their allocated service areas. Collection frequency should also be aligned with customer needs, contractual requirements, and available operational capacity to ensure regular service without creating unnecessary operating costs.

Moreover, municipal authorities should periodically review the duration and conditions of SWM service contracts to ensure that they remain supportive of financially sustainable service provision. Municipalities should also consider the financial implications of distance to designated disposal sites when planning and managing private SWM services. Where appropriate, municipalities should support container-based collection, taking into account the service area's characteristics and prevailing collection requirements. Waste collection frequency requirements should also balance reliable service delivery with private SWM firms' operational capacity. These measures can contribute to operating conditions that support the financial sustainability of private SWM service providers.

Declaration of Interest

The authors declare no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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