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Determinants of technical inefficiency in solid waste collection service

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ABSTRACT

BACKGROUND AND OBJECTIVES: Developing countries have been experiencing a rapid increase in their population. This comes in hand with more human activity and hence increased solid waste generation as one of the by-products. The continuous surge in solid waste generation is a challenge to these countries. Thus the need to make conducive decisions for solid waste management. To achieve this, in 2009, the Government of Tanzania privatized solid waste management services and enacted the Environmental Regulations Law. However, only 20% of solid waste generated in urban Tanzania is collected but instead dumped in landfills. In Morogoro, one of the urban centers in Tanzania, municipal officials can only collect and dispose in landfills less than 35% of the 200 tons of solid waste generated per day. This raises concerns about the technical efficiency of solid waste management and specifically solid waste collection services in Morogoro municipality. The purpose of this study is to measure technical efficiency and analyze the determinants of technical inefficiency for solid waste collection services in Morogoro municipality.

METHODS: Primary data was collected using a structured questionnaire with both open-ended and closed-ended questions. Morogoro municipality has a population of 290 waste management agents from whom a sample of 201 was selected using cluster and purposive sampling methods. A stochastic frontier approach was used to measure technical efficiency and analyze the factors determining technical inefficiency. STATA 14 software was used for model estimation and tests.

FINDINGS: Results show that technical efficiency for solid waste collection services in Morogoro Municipality is 81.56% that is below the technical efficiency threshold of 95%. Thus solid waste collection services in Morogoro municipality are inefficient. In addition, age of the waste management agent, number of houses participating in waste collection, and number of waste collection tools belonging to the waste management agents are significant determinants of technical inefficiency.

CONCLUSION: Results suggest an improvement in solid waste collection through increased wide service coverage. Increased community participation is a necessity and thus mass awareness campaigns are unavoidable. It is appropriate to procurement enough tools and labor force by the solid waste collection agents. Morogoro municipal authority should provide a stern law enforcement process.

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INTRODUCTION

Rapid urbanization of cities in developing countries may have negative externalities that include among others insufficient collection and improper disposal of Solid waste (SW). Solid waste disposal and collection has become a major concern worldwide (Madinah, 2016). It is projected that global waste will increase by 70% over the next 30 years, that is 3.4 billion tons of waste generated annually. While in Africa waste is expected to increase from 169,119 tons per day in 2018 to an average of 441,840 tons per day by 2025. In Tanzania, municipal waste is expected to increase from 2,425 tons per day in 2012 to 11,566 tons per day by 2025 (World Bank, 2018). Unfortunately, management of Municipal Solid Waste (MSW) is faced with a number of challenges. These include among others lack of financial resources, organization, and complexities due to differences in composition of MSW across municipalities in Africa (Abdel-Shafy and Mansour, 2018). Nathanson (2020) states that Solid Waste Management (SWM) is a process of collecting, treating, and disposing discarded solid materials because they served their purpose and are no longer useful Solid waste collected in sub-Saharan Africa accounts for only 46% of the waste generated. However, in Tanzania less than 50% of people living in urban areas are covered by the waste collection services (World Bank, 2016). In Tanzania, waste management is the responsibility of the urban authorities (Nyampundu *et al*., 2020). Nevertheless, the Government of Tanzania took different measures to increase Waste Collection (WC) and solve problems associated with uncollected wastes. The environmental SWM Regulations 2009 made under cap 191 of the "2004 environmental management act was enacted to integrate issues of natural resources, public health, and environment in a single legislative framework (URT, 2016; Shimba *et al*., 2021); Environmental awareness campaign through mass media and public advertisements was done to raise public awareness and community participation in SWM of which every Saturday is a national cleanup day (Lusagalika, 2020); As a result of the amended 2004 Environmental Management Act (EMA), the Tanzanian government got more active in the decentralization of SWM in Tanzania (URT, 2018). This was owing to a rise in the number of kilograms of solid waste produced, particularly in metropolitan areas (Shimba *et al*., 2021). The decentralization enabled all Tanzanian local governments, including Morogoro Municipal Authority, to allow Community-Based Organizations (CBOs) and private companies to collect rubbish in each municipal ward. Small Waste Management Agents (WMA) are formed from C.B.Os and private enterprises in each ward to function in every street of Morogoro municipal. Despite all of the precautions taken, Morogoro municipal authorities can collect and dispose of only 35% of the 200 tons of solid trash created everyday. Refuse pits are used to dispose of about 35% of uncollected garbage (Mollel, 2016). Although the Government of Tanzania has tried a number of programs to improve WC, barely 20% of solid waste generated in the metropolitan areas is collected and delivered to landfills. Given that water and sanitation difficulties account for more than 70% of infections detected in Tanzanian health institutions, this situation raises worries about WC in Tanzania (Jumanne, 2019). Borrowing from the Stochastic Frontier Analysis and model (SFA) by Charnes *et al.,* (1978), this may be triggered by WC efficiency of less than 95%, which is a Technical Efficiency (TE) threshold. Higher TE in WC indicates WMA collects the most waste with their inputs, allowing them to collect a higher percentage of waste created. This challenge is exemplified by minimal public participation in WC, as the bulk of the public has no sense of ownership. Even if the media attempted to deliver powerful information for urban cleanliness, it was revealed that many people who migrated from their native/home places and settled in big cities developed a sense of not being at home. This feeling pervades many residents' brains, making them feel as if they have no control over their settlement environment (Lusagalika, 2020). In the world's greatest cities, such as Hong Kong, about 70% of municipal solid waste (SW) has been dumped to landfills since 1998, with just around 30% recovered for recycling, implying that more than 99 percent of waste generated is collected annually (Cohen *et al*., 2015). The world's most sophisticated cities, such as Paris, are struggling to expand garbage recycling, whereas WC is almost unaffected (Ferrant *et al.,* 2019). There hasn't been much written about Solid Waste Collection (SWC) as a separate procedure with an emphasis on the WC service providers' side in Morogoro and/or Tanzania. Several studies focused on waste recycling and Waste Management (WM) as a full process, and one illustrated Morogoro's WC capacity in a nutshell using data from only four WMAs (Shimba *et al.,* 2021). In Morogoro SWC, there is space for significant improvement. The purpose of this study is to provide information on the current condition of SWC in Morogoro as well as solutions for improving WC. Waste treatment and management in developing countries is almost impossible without first improving the WC system, which appears to be a huge problem at the individual household and municipal level due to high population expansion in developing countries (Malata, 2019). The major objectives are to determine how effective WMAs are in collecting solid waste using existing inputs, as well as to integrate and construct inputs (people, garbage collection equipment, and trucks) that will work together to collect the maximum amount of waste possible for each. This will automatically raise the percent of SW gathered, allowing focus on improving the next phases of WM, that is treatment and dumping (for untreatable waste). The goal of this article is to evaluate the amount of TE on SWC services and to investigate the factors that influence WMA technical inefficiency in WC services. The current study has been performed in Morogoro municipality in 2020.

MATERIALS AND METHODS

Survey Design and Data Collection

Using population cluster sampling and purposive sampling approaches, a cross-sectional research design was employed to collect extensive information. Out of the 29 wards in Morogoro Municipality, cluster sampling was utilized to choose 22 with waste management services (Fig 1). The wards were chosen based on their proximity to Morogoro Municipal Center. The respondents in this study, who are representatives of a private company or group responsible for collecting solid waste on selected streets in the Municipality of Morogoro, were from the wards of Kingo, Mji mkuu, Mji mpya, Boma, Sultani, Kihonda magorofani, Sabasaba, Kiwanja cha ndege, Mazimbu, Uwanja wa taifa, Kingurwila, Tungi, Bigwa; Lukobe; Kilakala; Kichangani; Kihonda; Mbuyuni; Mafiga; Mwembesongo; Chamwino and Mafisa. The WMA were then purposefully selected from each ward/ segment of the municipality according to their working streets. 6-15 agents operating in each of the 22 wards/segments (each agent operating in one street) were purposely selected to make a total sample of 201 respondents from a population of 290 WMA. This study used primary data collected from respondents by filling out structured questionnaires and face-to-face interviews. The questions were both open-ended and closed-ended to give an opportunity for respondents to express their opinions and thoughts. The information obtained from the questionnaire was targeted to achieve the objectives of the research. The data was collected between April 15 and May 15, 2020. It is situated between Tanzania's main commercial hub (196 kilometers west of Dar es Salaam) and the country's capital city (260 kilometers east of Dodoma). Morogoro Municipality is located in Tanzania's eastern region (Fig. 1), with a population of 305,840 according to 2012 Census. It is situated between Tanzania's main commercial hub (196 kilometers west of Dar es Salaam) and the country's capital city (260 kilometers east of Dodoma). Furthermore, Morogoro Municipality connects highways for those traveling to Dar es Salaam for business from the central and western regions of Tanzania, as well as those from the southern highlands. As a result, Morogoro municipality has traffic congestion as people link their travels to other regions of the country. The mobility of people and vehicles increases the volume of waste generated in the municipality, necessitating the use of solid waste collection services.

A*nalytical Framework*

In economics, Pareto optimality is the most important valuation principle for efficiency analysis. Efficiency has been well-defined and studied in a variety of ways, including economic, technical, and allocative efficiency. Whereas some studies use randomized control experiments (Amin and Salihoglu, 2020); data envelopment analysis (Jafari *et al.,* 2022) and a meta-analysis (Hoang-Khac *et al.,* 2021) to evaluate efficiency, this study focused on TE to see how WMA use their inputs

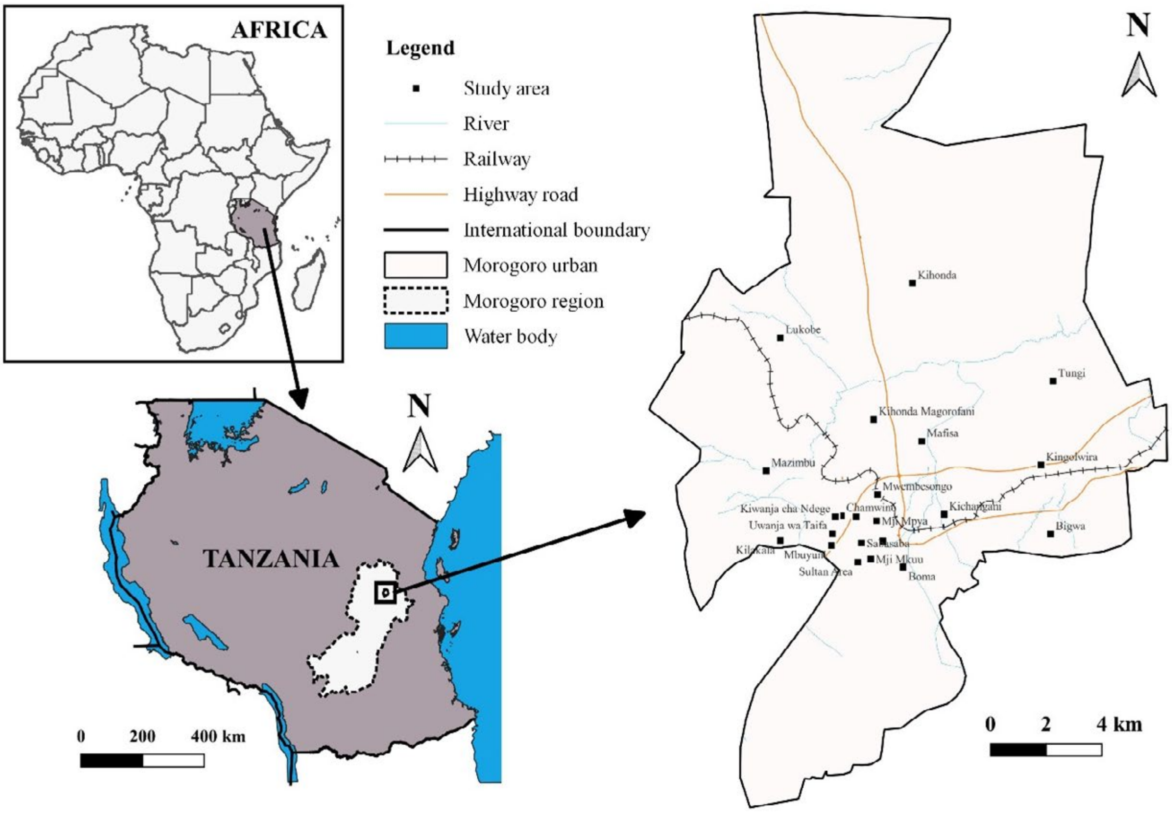

Fig. 1: Map of the study area of the Municipality of Morogoro from Morogoro Region in Tanzania

to maximize output (waste collected) using the Stochastic Frontier approach (Battese and Corra, 1977). Alvares and Crespi (2003) and Varabyova, and Schreyögg (2013) categorized techniques of efficiency estimation into parametric and non-parametric methods. The parametric methods use econometric techniques based on the assumption that the error term establishes two components. Statistical noise or unpredictability is represented by the first component, while technical inefficiency is represented by the second. SFA, a parametric technique first described by Farrell in 1957 and expanded by Aigner, Schmidt, and Lovell in 1977, was employed in the study. This model is notable in that, in addition to capturing the efficiency term, it also captures the impacts of exogenous shocks that are beyond the control of the units of analysis (Watundu *et al.,* 2021). The Cobb-Douglass production frontier is the simplest and most constrained version of SFA (Battese and Corra, 1977). The Cobb-Douglas production frontier takes the form of (Eq. 1):

$$Y_i = X_i\beta + \left(V_i + U_i\right) \text{ Where i=1, 2, 3…n} \quad (1)$$

Where Y_i is the output or logarithm of production of the i^{th} WMA, X_i is the vector of input of the i^{th} WMA, β is the vector of coefficient to be estimated, V_i signifies random variables expected to be independently and identically distributed, U_i signifies random variables assumed to explain technical inefficiency in production and expected to be identically distributed. Parametric models consider the description of production function and state the technological association between inputs and resulting outputs. This is a distinctive feature of this method and an advantage over non-parameter models that do not consider exact forms of production functions generating outputs from inputs used (Coelli *et al.*, 1998). Another potential advantage of parametric models over non-parametric model is that it accommodates random variations in output and therefore more reliable under normal working conditions. One of the key weaknesses of the parametric model that it is impossible to apply in a small sample size, in addition it can be used to model multiple-output technologies which make it more complex and it entails stochastic multiple output distance functions, and raises complications for outputs with zero values (Charnes *et al.,* 1978). According Lancaster (1966), SFA is an extension of conventional production function approach used to estimate output from production against the value of input which is labor and capital where it is assumed that production is efficient when a producer produces along the production possibility frontier and the production graph only diverges from the frontier due to random shock or an error term which is presented by letter V.

A production function of any WMA can be briefly stated as (Eq. 2);

$$Y_{i,} = f\left(X_{i,}\beta\right) \tag{2}$$

Production can be affected by the degree of efficiency of WMA that can result in less waste collection compared to the planned level. Efficiency can enter production function as (Eq. 3):

$$Y_{i,} = f\left(X_{i,}\beta\right)\varepsilon_i \tag{3}$$

Where ε_i stands for the level of WMA efficiency, and it ranges between 0 and 1. If the value is equal to 1, it implies that the WMA has attained optimal output given the technology and all other inputs used in waste collection. If $\varepsilon_i \leq$ 1, the output is inefficient thus WMA have not utilized their inputs X_i to their maximum capacity, with the assumption that if output is positive (y_i > 0), the degree of TE is also positive (ε_i >0).

The model is written as (Eq. 4):

$$=+\ (-u_i) \tag{4}$$

Or in log form as: (Eq. 5):

$$= + v_i - u_i \tag{5}$$

According to assumptions, the mean of this model is a function of independent variables or people's specific factors. Technical inefficiency could then be described as in given model form: (Eq. 6):

$$= \delta_i Z_i + w_i \tag{6}$$

Calculation of TE was observed by dividing current output by maximum feasible output from minimum resources (Taymaz and Saatci, 1997). Taking into account the substitutions between capital and labor (Reynes, 2019). The function is summarized in natural logarithms as follows (Eq. 7):

$$Iny_i = In\beta_0 + \sum_{j=1}^{k}\beta_j\, In\left(X_{,jik}\right) + v_{i,} - u_i, \tag{7}$$

Where; $y_{1,=}$represents output (SW collected), $X_{,jik}$ is a vector of quantities of inputs used by WMA in (SW) Solid Waste Collection services $\beta_0$and β_j are unknown coefficients of parameters to be estimated, $u_i = -ln$ is a non-negative one-sided error term associated with technical inefficiency, and v_i is a random shock, that can capture variation in WMA output due to factors outside its control (It ranges from 0.00 to 0.05). TE can then be presented as (Eq. 8):

$$\text{TE}=\ Y_i = \frac{f\left(x_i;\beta\right)\exp\left(v_i - u_i\right)}{f\left(x_i;\beta\right)\exp\left(v_i\right)} = \exp\left(-u_i\right) \tag{8}$$

For 0 ≤ Y_i ≤ 1, Y_i is WMA TE rate in providing WC service.

The maximum likelihood technique was used in estimation of the model. The estimated model was also used to determine factors influencing the inefficiencies in SWC. The estimated model was also utilized to find out what factors affect SWC inefficiency. The study used the same function for the model in (Eq. 5) to determine how different parameters (A = Number of households inside the street WMA operations; B = Number of participant houses in waste collection; C = Number of houses with waste separation (sorting) practice; D = Number of waste collection delays; E = Age of waste management agents) influence the amount of technical inefficiency in SWC. Y_i=*1* not only indicates 100 percent efficiency, but it also shows random errors that create deviations from the frontier. These are the deviations from being 100 percent efficient towards achieving target output owing to random effects on the production frontier. Hence justifying the use of SFA. The study used one-step approach adopted from Battese and Coelli (1995). The approach facilitated the analysis of the determinants of SWC technical inefficiency and computation of TE at the same time. STATA Software (Version 14) was used in analysis. The coefficient was reversed in interpretation since the dependent variable was technical inefficiency and not TE in nature. This means that increasing variables with negative sign increased TE, while increasing variables with positive sign decreased TE. The model was thus specified to include both inputs used and the determinants of technical inefficiency as (Eq. 9):

$$Iny_i = In\beta_0 + \sum_{j=1}^{k}\beta_j In\left(X_{,jik}\right) + A - B - C + D + E + v_{i,} - u_i, \quad (9)$$

Where, $X_{,jik}$ is a vector of quantities of inputs used by WMA in SWC services. The inputs used by WMA included (K1= Number of workers in WMA, K2= Number of vehicles used in WC, K3= Number of wheelbarrows, K4= Number of hoes and K5= Number of shovels where all inputs which could affect WC). A, B, C, D and E were determinants of technical inefficiency in WC. Iny_i is the output (amount of waste collected).

RESULTS AND DISCUSSION

Descriptive Statistics of the variables used

The study obtained the measures of central tendency; mean, variance, maximum, and minimum values of variables utilized in the study to define the entire set of data used in the model. (Table 1).

From Table 1, the average of number of houses in each street was 128. This shows that Morogoro municipal has very large number of houses per street and this might hinder proper SWC services. Out of all houses in the street on an average of 44 houses pay for their SWC fees and participate well in SWC. This indicates that a very small number of people are willing to participate in SWC. Number of houses with waste separation (sorting) of recyclable from non-recyclable waste was only 1. This implies that houses do not separate their waste before

Table 1: Descriptive statistics

Variable Name	Description	Observations	Mean	Standard. Deviation	Min	Max
A	Total number of houses in each street of operation for the waste management agents (CBO's/ groups/ private waste management agent with mandate)	201	128	69.4034	25	383
B	Number of participant houses (houses which pay for service on time and collects their houses waste ready for waste management agents per each street)	201	44	21.78459	11	86
C	Number of times the waste collection and dumping process is delayed making waste to still be present in people's houses or in streets	201	1	1.043983	0	3
D	Number of houses which practice waste (sorting) separation in the streets	201	2	1.087102	1	5
E	Age of each waste management agent operating in a street	201	50	10.01403	26	67
K1	Number of workers employed within each waste Management agent	201	4	1.326762	1	7
K2	Number of vehicles used with each waste Management agent in the waste collection process	201	2	1.028282	1	4
K3	Quantity of wheelbarrows employed in the waste collection process	201	3	1.043769	1	5
K4	Number of hoes employed in the waste collection process	201	4	1.299024	2	8
K5	Number of shovels employed in the waste collection process	201	3	1.183615	1	7

Table 2: Technical efficiency of the waste management agents

Observation	Mean	Std. Dev.	Min	Max
201	0.8156659	0.2461313	0.1470303	0.997838

being collected by WMA. On average waste are not collected by WMA 2 times in a month. The mean age of the WMA was 50 years. This implies that WMA are matured enough to know their roles in SWC, and how important their performance is to the community at large. The mean/average number of workers in the WMA was 4 workers. The average number of vehicles used each WMA was 2. This shows a low usage and availability of vehicles for SWC by WMA since, among the vehicles used by every WMA in Morogoro municipal, 1 vehicle is from the municipal council. The vehicle is used to collect the waste from other small collection points of the streets to the dumpsite. The average number of hoes used in WC process was 4. The mean/ average number of shovels used in WC process was 3. The mean/average number of wheelbarrows used in WC process was also 3. Generally, few tools were owned by WMA compared to the average number of workers. This showed a low availability and utilization of SWC tools by the WMA since, they had lower average compared to the average number of workers which were 4 workers. This had an impact of number of times waste are collected and the ability to collect waste in all streets effectively.

Estimation of Technical Efficiency

Level of TE was estimated (Table 2) and results explains how WMA in Morogoro municipality use the input available to generate the output (kilograms of WC).

The TE score was estimated following Jondrow *et al.,* (1982) procedure in analyzing TE through one-step approach of the SFA. Findings show that the average or mean efficiency is 0.8156659, meaning that the WMA utilized their inputs by 81.56% in WC. Since the estimated TE is less than the efficiency threshold of 95%, this implies that the waste management agents are technically inefficient in WC. SFA was estimated using a one-stop strategy to acquire determinants of technical inefficiency in WC, that comprise estimating TE and analyzing determinants of technical inefficiency in one model at the same time (Table 3).

The estimated model was proven to be significant, since the Prob> chi2, U sigma, V sigma, Sigma u, and Sigma v were all significant at 1% level. The dependent variable in this model is the nature of technical inefficiency. Kilograms of waste collected per month (lnoutput) was the output variable in this model. Independent variables with a positive coefficient were considered to increase technical inefficiency while, independent variable with a negative coefficient were considered to decrease technical inefficiency. The model provides the frontier regression model containing input variables with the number of hoes having a negative coefficient of -0.1657956 and significant at 5% level. This implies that ownership of one additional hoe will lead to a decrease in Kilograms of solid waste collected by 16.5% if other covariates remain constant. In addition, the number of vehicles had a positive coefficient of 0.1523984 and was significant at 5%. This implies that ownership of one additional vehicle by WMA will increase Kilograms of Waste Collected by 15% if other factors remain constant. Number of shovels had a positive coefficient of 0.3388639 and was significant at 1%. This implies that ownership of one additional shovel by WMA will increase the Kilograms of waste collected by 33.8%, if other factors are kept constant. These results were similar to those of (Lv *et al.,* 2021) in the study of the influences of fixed assets on corporate performance - Evidence from manufacturing-listed companies in China, which found out that growth rate of fixed assets investment had a significant positive relationship with corporate performance manufacturing companies. This could also be interpreted as fixed/ capital assets (like hoes, vehicles and shovel) growth rate have significant positive relationship with manufacturing (production) companies. The growth rate of fixed assets refers to the ratio of the annual net increase in fixed assets to the original total fixed assets, which reflects the scale and speed of the growth of fixed assets. Lv *et al.* (2021) also found out

Table 3: Results of the determinants of technical inefficiency

Stochastic frontier normal/truncate normal model						
			Number of observations =		201	
			Wald chi2(5) =	60.47		
			Prob > chi2 =	0.0000		
Log likelihood = -67.4536						
lnOutput*	Coefficient	Standard Error frontier	Z	P>|z|	[95% Conf. Interval]	
Constant	9.26821	0.1809012	51.23	0	8.91365	9.62277
lnK1	0.3207087	0.0865642	3.7	0	0.151046	0.490371
lnK2	0.1523984	0.0590766	2.58	0.01	0.03661	0.268187
lnK3	-0.001201	0.0675641	-0.02	0.986	-0.13362	0.131222
lnK5	0.3388639	0.0683955	4.95	0	0.204811	0.472917
lnK4	-0.1657956	0.0706918	-2.35	0.019	-0.30435	-0.02724
Constant	1.177278	0.4396219	2.68	0.007	0.315635	2.038921
A	0.0000514	0.0011332	0.05	0.964	-0.00217	0.002273
B	-0.0802677	0.0172458	-4.65	0	-0.11407	-0.04647
C	0.031624	0.0689019	0.46	0.646	-0.10342	0.166669
D	0.0232851	0.0626924	0.37	0.71	-0.09959	0.14616
E	0.0179992	0.0060459	2.98	0.003	-0.00615	0.029849
Usigma constant	-2.813555	0.6984824	-4.03	0	-4.18256	-1.44456
Vsigma constant	-2.287854	0.1204239	-19	0	-2.52388	-2.05183
sigma_u	0.2449313	0.0855401	2.86	0.004	0.123529	0.485645
sigma_v	0.3185656	0.0191815	16.61	0	0.283104	0.358469
lambda	0.7688568	0.0951803	8.08	0	0.582307	0.955407

*In represents natural logarithm of variables used in the model

that the quality of fixed assets had a weak positive relationship with fixed assets. In other words, high quality of fixed asset relatively reduces the cost of operation and increase corporate performance (which is also performance of manufacturing/production companies). This can also imply that, increase in fixed/capital assets like hoes, shovels and vehicles for WMA can relatively reduce the day to day operating costs like these assets' rental costs. The operating cost reduction will go hand in hand with increase of WMA performance in production of solid waste collection service. The number of workers had a positive coefficient of 0.3207087 and significant at 1%. This implies that employment of one more worker by WMA will increases WC by 32%, if other factors remain constant. Similar findings were explained by (Begum *et al.*, 2019) in the study of factors affecting TE of turmeric farmers in the slash and burn areas of Bangladesh in 2019. Results indicated that, training and farm visits of the extension workers have a significant impact on technical inefficiency of farmers in the slash and burn agriculture in Bangladesh. This implies that training significantly improves TE and output of turmeric farming through increasing farmer's consistency in following the turmeric farming and management practices properly. Similarly, results of the SFA imply that presence of more skilled labor in production of any good or service improves both TE and output of the process. In addition, results in table 3 show that, the significant determinants of technical inefficiency of WC process were; Number of participant houses in the SWC process. Number of participant houses was negative and significant at 1% level with a coefficient of -0.0802677. This implies that increase in the number of participant houses decreases technical inefficiency by 8% if other factors are kept constant. To attain 100% TE, more participant houses are needed, if other factors are kept constant. Sinthumule and Mkumbuzi (2019) had similar results in the study on participation in community-based solid waste management in Nkulumane Suburb, Bulawayo, in Zimbabwe they found involuntary and/or lack of community, participation through voluntary collecting of household wastes ready to be collected by the WMA was among of the factors causing difficulties in SWM. The lack of community voluntary participation in Nkulumane suburb SWC showed 69.6% of the community dumped waste in bins only because of their fear of fines and punishment not because they perceive it wrong or bad for the environment. It was also found that 20.27 of respondents used to burn their wastes at home. This proves very low community voluntary participation on WC. Similarly, in Morogoro municipal with only 44 houses on average pay for SWC fee on time and get their houses waste ready for collection voluntarily. Age of WMA affected technical inefficiency since it was significant at 1% with a coefficient of 0.0179992. This implies that increase in age of WMA increases technical inefficiency by 1.7%, if other factors were kept constant. This concludes that, younger people performs better in SWC service provision by been able to collect more kilograms of wastes with the use of the same inputs/equipment. Similar results were obtained by Wang *et al*., (2017), in a study with the title aging and inequality, the perspective of labor income share" conducted, which confirmed the positive relationship between aging and income inequality. The study also showed that the negative effect comes from the shrinking labor force due to aging rather than the lowering of the average wage. This concludes people with old age have lower income share because of lower labor force. Results of this shows that the older the WMA the lower the productivity since there is low will power for work. Similar results were reported in 2020 in the World health organization (WHO) study, that focused on age among the factors of productive capacity. The study concluded that for work in need of strength (like WC), aging deteriorates productivity (World Health Organization, 2020). Contrasting results were reported by (Malata, 2019) in a study titled prediction of amount of solid waste in Morogoro municipality. The main goal was to find right age for people involvement in WC within each house by collecting houses wastes to their bins. It was observed that, older people were better than youths since older people lived longer in their homes to know how to perform home choirs. The study had opposite results since it was based on in-house WC only. The work requires little energy, plenty of time with no payment which is suitable for old people as physical exercise. *Log-likelihood ratio test;* These results were also tested for significance by using log-likelihood values through likelihood ratio test statistics (Table 4). This test is recommended as the best method used to test the relevance of SFA (Kumbhakar e*t al.*, 2015). Where -2(Restricted log-likelihood value which is the Cobb-Douglas) -(Unrestricted log-likelihood value which is the stochastic frontier) = 99.83982, that is greater than 5.412 (The Critical value of 1 degree of freedom for the mixed distribution at 1% significance level as reported by (Kodde and Palm, 1986). Thus, the null hypothesis of the inappropriateness of SFA was rejected.

Results indicate that training significantly improves technical efficiency of turmeric farming, consistent with Karthick et al. (2013). The trained farmers are expected to follow the turmeric management practices
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Table 4: Results for the restricted log-likelihood test

Iteration 0: log likelihood = -117.37351

Generalized linear models	Number of observation = 201
Optimization : ML	Residual df = 195
	Scale parameter = .1940429
Deviance = 37.83836376	(1/df) Deviance = .1940429
Pearson = 37.83836376	(1/df) Pearson = .1940429
Variance function: V(u) = 1	[Gaussian]
Link function : g(u) = u	[Identity]
	AIC = 1.227597
Log likelihood = -142.0593524	BIC = -996.3061

Inoutput	Coef.	OIM Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Consant	7.763791	0.152931	50.77	0	7.464052	8.06353
K1	0.970911	0.080634	12.04	0	0.812871	1.12895
K2	0.193256	0.071857	2.69	0.007	0.052419	0.334093
K3	0.114924	0.083799	1.37	0.17	-0.04932	0.279167
K4	-0.0042	0.09003	-0.05	0.963	-0.18065	0.172258
K5	0.431853	0.086862	4.97	0	0.261608	0.602099

= -2*(-117.37351 - -67.4536) = 99.83982

Results indicate that training significantly improves technical efficiency of turmeric farming, consistent with Karthick et al. (2013). The trained farmers are expected to follow the turmeric management practices
properly, which might have led to higher efficiency for
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them.
training and farm visits of the extension workers have
a significant impact on technical inefficiency of farmers in the slash and burn agriculture in Bangladesh.
Results indicate that training significantly improve
The model had 201 observations, 0.000 probability meaning the whole set of data was significant and the log-likelihood values through the likelihood ratio test statistics proved this data's reliability on explaining technical inefficiency in WC.

CONCLUSION

The objective of this research was to estimate SWC's TE. The fact that WC is the first and most important stage of WM motivated this study. In addition, the study looked into the factors that contribute to technical inefficiency in Morogoro Municipality's SWC. The study used SFA on primary data obtained in Morogoro municipality from April 15th to May 15th, 2020 to achieve these goals. WMA had an average TE of 81.56 percent, according to the findings. The number of homes, cars, shovels, and personnel were important inputs determining the kilogram of SW gathered, while the age of WMA and the number of participant households in WC were major factors with relevant effects on technical inefficiency. These findings indicate that until the year 2020, WC alone was still a significant problem in Morogoro Municipality. Findings from this research will guide policy-makers and environmental managers to design and improve the effectiveness of recycling policies in Tanzania. Globally, this study adds to the literature in order to lay the groundwork for a successful SWC policy in the same social, cultural, and economic regions and/or states as Tanzania. The findings may also serve as a source of academic knowledge for a better understanding of the SWC process, its TE, and the factors that contribute to technical inefficiency in SWC in Morogoro. The knowledge of TE level in SWC and determinants of technical inefficiency helps SWM stakeholders to know the remaining percent to accomplish reaching TE threshold in SWC and to move on rectifying other phases of SWM. The knowledge of the determinants of technical inefficiency in SWC includes knowledge of how age of WMA and number of participant houses in SWC process affect the technical inefficiency in SWC. Results on age of the WMA show that the younger the WMA the better, indicating more youths are needed in SWC. Engaging more youths in provision of SWC service in the current and future will bring various environmental advantages. The advantages will be coming from positive values found in youths and needed for efficient in SWC which includes more drive, physical strength and good interaction with big part of the community (also mostly youths); Ensure increased long-term efficiency in SWC since youth have more assurance of longer life span than old individuals and reduce all health problems associated with unclean environment since youth will mostly increase efficiency in SWC. Engaging more youth will be more successful if it will coincide with assurance of good and timely payment of SWC fee to the WMA (which is part of participation). This study concludes that the more participant houses the higher the ability for WMA timely fee collection enabling them to call in more youths to engage in SWC service provision. The necessity for higher SWC participation was very clearly indicated by the results. This can be achieved through increased effective sensitization campaigns (both physical ways and through media) as well as practicing reasonable enforcement of law, with the aim of positive effect in SWC participation. The awareness and positive views on SWC participation from the campaign will ensure long-term achievement since every person (children to old adults) will be included.

The government through concerned ministries and other stakeholders may also make a close follow up on how SWC exercise is done by WMA; increase education on importance of WC, good and timely payment for the service so that all houses can pay for the services on time; supervise WMA in terms of ownership of tools used in SWC; Encourage WMA to keep their data concerning SWC; Encourage more WM campaign's and in-depth yearly researches on WM by higher learning institutions; Provide motivational knowledge, financial and material support to WMA according to their performance in their streets of operation. These changes will be helpful since, municipal council, wards/segments health officers and WMA will be able to; Monitor the efficiency progress of WC and WM work through yearly researches conducted; Know possible determinants of technical inefficiency on WM and how to overcome them. Citizens will also have a chance of providing their opinion of the WM service provided, their level of satisfaction and how they can help to increase WC as part of WM process. Apart from these results there are other areas in need of further research since there is still some literature gapes around SWM and WC areas with respect to Tanzania. Continuous yearly research could be conducted on the technical efficiency and factors affecting technical inefficiency on WC to keep track the progress of the results and if people take measures on the yearly research results. Another research can be on the level of citizen satisfaction from the TE in WC. Another research could be in the role of the government in WC TE. Another crucial area is the Role of Tanzanians University students (researchers) in WM. This is to have a clear picture of how well the researches done can help the society as far as WM is concerned. The research on TE in WC could also be done in different areas (Regions, cities, and towns) in Tanzanian to check if the findings will concur. Other researchers could also research the contributing factors to low participation in WC and/or WM.

AUTHORS CONTRIBUTION

A.J. Mzava, performed the literature review, data collection, analysed and interpreted data, prepared the manuscript text and manuscript edition. L.A. Chamwali performed data cleaning, interpreted data and manuscript edition. S. Watundu, performed data and results interpretation, proof reading and manuscript editing.

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CONFLICT OF INTEREST

The authors declare that, there is no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

β0 and βj	The unknown parameters to be estimated
CBO	Community Based Organization
Conf Interval	Confidence Interval
No of obs	Number of Observation
In	Represents the natural logarithm of variables used in SFA
SFA	Stochastic Frontier Analysis\Model
SW	Solid Waste
SWC	Solid Waste Collection
SWM	Solid Waste Management
T normal	Truncated Normal Model
TE	Technical Efficiency
WC	Waste Collection
u1 =	*-InƐi* A non-negative one-sided error term associated with technical inefficiency.
v1,	A random shock, that can capture variation in WMA output due to factors outside its control (It ranges from 0.00 to 0.05).
WMA	Waste Management Agents
WM	Waste Management
X, jik	A vector of quantities of inputs used by WMA in WC service.
Y1	The term of waste collection output.

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