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TRANSPORT

TECHNICAL EFFICIENCY OF RAILWAY TRANSPORT SYSTEM IN KENYA: A CASE OF THE STANDARD GAUGE RAILWAY TRANSPORT SYSTEM

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ABSTRACT

Purpose of the Study: The study's purpose was to investigate the level of technical efficiency of Kenya's standard gauge railway goods transport system from Fiscal Year 2018/19 to Fiscal Year 2023/2024.

Problem of Statement: According to Kenya Railways' Strategic Plan 2023-2027, the Corporation has been unable to maximize the value of its assets while also meeting increasing market demand. This is a clear indication that the SGR freight transport system must be efficient to meet the growing market's high demand.

Methodology: To achieve the study's objectives, a non-experimental research design was used. Stochastic Frontier Analysis was used to estimate the gauge's technical efficiency levels. The Stochastic Frontier Analysis results were then subjected to regression analysis using the Tobit model to identify the factors influencing the technical efficiency of Kenya's standard gauge railway transport system.

Results: The study found that the average technical efficiency levels for the Net Tonne Kilometre model were 0.94 (94%), while the revenue model was 0.873 (87.3%). The technical efficiency levels for the Net Tonne Kilometre model showed that the railway system is extremely effective at managing goods transportation, with only minor inefficiencies limiting its potential. However, the slightly lower average technical efficiency levels for the revenue model highlight a problem in translating operational success into financial performance. The inclusion of macroeconomic variables such as inflation and exchange rates in the models revealed more nuanced effects, with inflation having a negative impact on efficiency and exchange rates having a mildly positive effect.

Conclusion and Policy Recommendations: The study concluded that, while Standard Gauge Railway freight services have high technical efficiency in freight handling (94%), there is a significant gap in financial performance, with revenue efficiency of 87%. To address this, disconnect, policymakers were encouraged to adopt improved pricing strategies, cost management, and adaptability to macroeconomic factors, which are critical for maximizing the SGR's transformative role in Kenya's socioeconomic development and regional integration goals.

Keywords: *Technical Efficiency, Railway Transport System, Standard Gauge Railway Transport System, Stochastic Frontier Analysis*

INTRODUCTION

An efficient transport system is essential for urban life, international trade, and regional socioeconomic development (Kaiser & Barstow, 2022). According to the United Nations' Sustainable Development Goals (SDGs), well-developed transport infrastructure promotes economic growth, connects citizens to job opportunities, and improves safety (World Bank, 2002). Mobility and transport systems have historically shaped nations, determining where socioeconomic activities, city structures, and lifestyles take place around the world (Bayane et al., 2020). Rail transport has a 500-year history, beginning with human or animal-powered systems on wooden or stone rails. The modern rail system, which employs steam locomotives, began in England in the 1820s and was the first practical mechanized land transport. By 1964, Japan introduced high-speed rail with the Shinkansen line between Tokyo and Osaka, revolutionizing short-haul transport by replacing many flights and automobiles (Bešinović 2020).

The World Bank is the largest financier of transport projects, particularly those that are climate-friendly. In FY 2023, it approved 20 new projects totaling $2.9 billion, including Standard Gauge Railway (SGR) projects. Currently, 165 active transport projects worth $33.2 billion account for approximately 10% of World Bank lending (World Bank, 2024). Rail transport remains the most cost-effective mode of global freight movement, contributing significantly to economic growth (Cristea et al., 2013). Many developed countries, including India and the United Kingdom, have expanded their rail networks to promote regional and global market integration (Yu, 2017). Global railway freight transport is steadily expanding, with the market valued at $172.64 billion in 2022 and expected to reach $217.74 billion by 2028, representing a 3.94% compound annual growth rate (CAGR) (OECD, 2024).

On a regional scale, Africa has welcomed a resurgence in rail transport, in line with the African Union's (AU) Agenda 2063, which emphasizes rail as critical to stimulating trade and sustainable development. Agenda 2063 aims to establish a high-speed train network connecting major African cities by 2063 (African Union, 2023). Several SGR projects have emerged across the continent, including the proposed rail connection between Ethiopia and Sudan and the Djibouti/Addis Ababa SGR, which was completed in 2018. This railway reduces the travel time between Addis Ababa and the Port of Djibouti from three days to 10-12 hours (African Union, 2023). Another important project is Tanzania's Dar es Salaam/Dodoma SGR, which aims to connect the port city of Dar es

Salaam to Dodoma and eventually to the Burundi border (African Development Bank Group, 2020).

Evaluating the efficiency of rail transport systems, particularly using methods like Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA), entails determining the relationship between input and output variables. The rail system's input variables include fuel, labour, rolling stock (such as locomotives and waggons), infrastructure, and maintenance. These inputs represent the operational costs and resources required to keep the system running (Marchetti & Wanke, 2019). Fuel consumption, for example, has an impact on efficiency because it influences operational costs and the environment. Efficient fuel use can lower the cost per kilometre of transporting goods, increasing technical efficiency (Berndt & Morrison, 2020). The reliability of locomotives is another critical factor. Unreliable trains cause delays, downtime, and increased maintenance costs, reducing efficiency (Pittman, 2018). Improved locomotive reliability through proactive maintenance and system upgrades can boost operational efficiency by making the best use of available resources (Szkoda et al., 2021).

Output variables assess the system's performance, with goods transported serving as a key indicator. The volume of goods moved over time provides a direct measure of efficiency. When inputs such as fuel and reliable locomotives are used effectively, freight volumes rise, increasing the system's technical efficiency (Archetti et al., 2022). Revenue from goods operations is also an important output variable. Higher revenues indicate greater efficiency, provided that operational costs are reduced and routes are optimized (Zhang & Wu, 2023). Net Tonne Kilometres (NTK) are another important output metric that reflect the weight of goods transported over distance. High NTK values indicate efficient capacity utilization because the system maximizes freight volume while reducing fuel consumption and other inputs (Andersson et al., 2019). Technical efficiency in rail transport occurs when the system maximizes outputs while using the fewest possible inputs. SFA modelling, which is frequently used to assess such efficiency, compares different decision-making units (in this case, rail transportation systems) based on their input-output ratios. SFA identifies the most efficient systems and highlights areas for improvement. For rail systems like SGR, optimizing input variables like fuel and locomotive reliability while maximizing output variables like freight volume, revenue, and NTK can significantly improve operational efficiency (Victorino & Pena, 2023).

STATEMENT OF THE PROBLEM

The railway transport system is critical to Kenya's public transport sector, especially since the introduction of the Standard Gauge Railway, which aims to modernize and improve rail transport efficiency (KRC, 2023). While the SGR has the potential to revolutionize transport by reducing transit time and costs and stimulating urban development (Bouraima et al., 2020; Taylor, 2020), significant gaps remain in understanding the factors influencing its efficiency. According to Kenya Railways' Strategic Plan 2023-2027, the company has been unable to maximize the value of its assets while also meeting increasing market demand. This is a clear indication that the SGR freight transport system must be efficient in order to meet the high demand of the growing market. Furthermore, one of Kenya Railway's strategic goals in the plan is to improve rail asset technical and operational efficiency by optimizing rail asset availability, reliability and utilization for increased Net Tonne Kilometre (KRC, 2023).

Similarly, while there has been empirical research on SGR performance in various contexts, studies on SGR freight technical efficiency in Kenya have not entirely focused on how technically efficient the railway system has been in the years since its operationalization (Zhu et al., 2023; Githaiga, 2021). This necessitates thorough evaluations of SGR freight technical efficiency and an understanding of the factors that influence its performance. As a result, this study aims to contribute to the discourse on transport efficiency by investigating the level of technical efficiency of the standard gauge railway goods transport system in Kenya and identifying the factors that influence it.

OBJECTIVES OF THE STUDY

The general objective of this study was to investigate the level of technical efficiency of the standard gauge railway freight transport system in Kenya for the period 2018 to 2023.

The specific objectives are:

i. To determine the technical efficiency of the standard gauge railway freight transport system in Kenya for the period FY2018/19 to FY2023/24.
ii. To determine the factors affecting the technical efficiency of the standard gauge railway freight transport system in Kenya for the period FY2018/19 to FY2023/24.

RESEARCH QUESTIONS

i. What is the technical efficiency level of the standard gauge railway freight transport system in Kenya for the period FY2018/19 to FY2023/24?

ii. What are the factors affecting the technical efficiency of the standard gauge railway freight transport system in Kenya over the period under consideration?

THEORETICAL LITERATURE

Production Theory

The theory was initially proposed by Cobb, Charles W., and Paul H. Douglas in the late 1920s (Cobb & Douglas, 1928). The theory explains the principles by which the producers make decisions on how to use the factors of production to optimize production. This refers to the connection between the prices of goods and the costs (such as wages or rents) associated with the factors of production utilized to create them. Similarly, it addresses the interplay between the prices of goods and production factors and the quantities of both goods and factors that are produced or consumed. (Thirlwall & Pacheco-López, 2017; Witt, 2016).

Therefore, "production is a process of combining various inputs to produce an output for consumption". It is the act of creating output in the form of a commodity or a service which contributes to the utility of individuals (Cobb & Douglas, 1928; Walker, 2021). In the context of the SGR, the inputs include the infrastructure investments, operational expenditures, labor force, and technology used to manage and run the railway system. The output is measured in terms of freight transported, service reliability, transit times, and overall customer satisfaction. The theory suggests that for the SGR to operate efficiently, it must optimize the use of these inputs to achieve the highest possible output without wasting resources. For instance, efficient resource allocation would involve ensuring that the SGR maximizes the use of its rolling stock, minimizes operational delays, and employs effective logistical planning to meet the demand for freight transport.

Measurement of Technical Efficiency

Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis is a technique used for frontier estimation, relying on a predefined functional relationship between inputs and output. This specified functional form serves as a foundation for applying econometric methods in the estimation process. SFA recognizes the presence of random noise surrounding the estimated production frontier. In its simplest application, involving a single output and multiple inputs, the method estimates outputs based on a functional relationship between inputs and outputs; i.e.

$y_i = f(x_i, \beta) + \varepsilon_i$……………………………………………………………..….. 2.1

Where; y is the output, $x_i$the inputs, β parameters to be estimated; and ε is the residual.

In 1977, Aigner, Lovell, and Schmidt, along with Meeusen and Van den Broeck, independently introduced the stochastic production function model, which was represented in the form of a log-linear Cobb-Douglas function;

$lnQ_{\boldsymbol{i}} = x_i{}'\beta + vi - ui$……………………………………………………….……..….. 2.2

Where; Qi represents the output variable; xi denotes a vector of relevant input variables, vi is the random error term capturing statistical noise and ui is a non-negative component of the error term reflecting technical inefficiency. This model accounts for technical inefficiency while also recognizing that random shocks beyond the producer's control can influence output. A notable advantage of stochastic production frontier models is their ability, at least in principle, to distinguish the effects of factors such as variations in labor and machinery performance, unpredictable weather, or random luck from variations in technical efficiency.

Equation 2.2 represents a stochastic production function, as the output values are constrained above by the stochastic (random) variable $exp(x_i{}'\beta)$. In this instance, the Cobb-Douglas stochastic frontier is expressed in the following form:

$Q_{\boldsymbol{i}} = \exp(\beta 0 + \beta i\ lnxi + vi - \ ui$…………………………………..…………….……..….. 2.3

When the outputs and inputs of two firms, A and B, are plotted, and the deterministic component of the model reflects diminishing returns to scale, Firm A utilizes an input level XA to produce an output quantity QA, while Firm B employs an input level XB to generate QB. In the absence of inefficiency effects (UA=0 and UB=0, where UA and UB represent the inefficiency effects for Firms A and B respectively), the frontier outputs would be represented as follows:

$Q_A = \exp(\beta 0 + \beta i\ lnxA + vA$………………………………………………………... 2.4

$Q_B = \exp(\beta 0 + \beta i\ lnxB + vB$……………………………………………………….. 2.5

For Firm A, the frontier output exceeds the deterministic component of the production frontier solely due to a positive noise effect (vA>0). Conversely, the frontier output falls below the deterministic component for Firm B because the noise effect is negative. The observed production for Firm A is below the deterministic frontier because the combined effect of noise and inefficiency is negative. Observed outputs can only exceed the deterministic frontier when the positive noise effect outweighs the inefficiency effect, i.e., $vA - uA$.

The most widely used output-oriented measure of technical efficiency (TE) is the ratio of the observed output to the corresponding stochastic frontier output. That is;

$$TE_i = \frac{Q_i}{\exp\{x_i'\beta + vi\}} \quad \ldots 2.6$$

$$TE_i = \frac{\exp\{x_i'\beta + vi - ui\}}{\exp\{x_i'\beta + vi\}} \quad \ldots 2.7$$

$$TE_i = e\dot{x}p\{-ui\} \quad \ldots 2.8$$

This measure of TE takes the values between zero and one. It measures the output of the ith firm relative to the output that could be produced by a fully efficient firm using the same input vector.

This measure of technical efficiency ranges between 0 and 1, indicating the output of the i-th firm relative to the production that a fully efficient firm could produce using the same input vector.

EMPIRICAL REVIEW

Technical Efficiency of SGR Transport System

Zhu et al. (2023) examined the perceived socio-economic impacts of the Kenyan SGR through an original survey involving 132 experts and interviews with 91 community residents across five cities and towns. The research revealed that both local and international stakeholders place a higher priority on socio-economic impacts compared to other areas. However, tensions persist between economic growth and environmental conservation at the local level. The SGR was found to significantly benefit tourism and moderately enhance employment, with variations in outcomes depending on business size, sector, and location. The study recommended integrating physical infrastructure with supportive services to foster equitable growth and emphasized the need for further research into the technical efficiency and operational challenges of the SGR.

Oyugi (2022) explored ways to optimize freight transport using standard gauge railways, focusing on the factors that affect revenue collection for the SGR. The study was grounded in optimization theory and utilized both qualitative and quantitative methods. Qualitative findings identified key operational challenges, ranked in order of significance, as inadequate capacity, multiple handling processes, labor shortages, uncoordinated operations and planning, limitations in SGR network infrastructure, high costs, and poor communication. The research also proposed several remedies, including the development of an integrated transport policy, the implementation of appropriate capital allocation strategies, the merger of the Kenya Ports Authority (KPA) and Kenya Railways Corporation (KRC), and a review of SGR freight tariffs.

Sabrie (2022) aimed to identify solutions to the challenges faced by the SGR, Kenya's largest railway transport system, to enhance its operations. The research employed a qualitative methodology, focusing on collecting and analyzing non-numerical data to gain insights into ideas, perspectives, and experiences. Thirteen participants were involved in the study, including general managers, train crews, and passengers. Data was gathered through questionnaires, which were then cleaned and coded to minimize errors before being analyzed using Microsoft Office Excel.

Factors Affecting the Efficiency of the SGR Transport System

Mchome and Nzoya (2023) aimed to explore the causes of International Financial Institutions-Performance Standards (IFC-PS) through the SGR Projects that escalate costs and how to address them. The Tanzania SGR Lot 1 Project that covered 205 km from Dar es Salaam to Morogoro was selected as a case study. The methods used for data collection involved literature review, focus group discussions and interviews. The results and findings show a gap between the IFC-PS and the National Laws and Regulations that escalates costs of the projects if funds from the IFIs were to be secured. To bridge the gap, it is recommended that the African countries should engage into negotiations with the IFIs to agree to waive IFC-PS conditions that escalate costs provided they are adequately covered in the national laws and regulations; engagement of locally established national and regional financial institutions; and the responsible government institutions in the African countries should sit together for assessment and review of the IFC-PS against the national laws and regulations.

Zhu et al. (2020) aimed to summaries the main flaws of current BRI evaluation frameworks, suggest a systematic evaluation framework elicitation method based on BRI subject matter expert input and stakeholder participation, and apply an interim evaluation framework to the Mombasa-Nairobi SGR project in Kenya. The study showed factors that affect SGR performance. The Kenyan government's successful negotiations with the China Road and Bridges Corporation (CRBC) allow local businesses to source materials, services, and jobs. The SGR has hired and trained local workers during construction, aiming for 90% local staff by 2027. CITIC has responded to Kenya's need for tech transfer by providing various training types, leading to local management positions and specialised on-the-job training. Governance and corruption issues, especially regarding SGR land allocation, have increased distrust in the government and raised concerns about transparency in construction and operation agreements. Chinese Exim Bank loans funded the SGR project, raising debt sustainability issues. The SGR was built with environmental and ecological considerations in mind, including wildlife passages and conservation practices to reduce biodiversity and ecological impact. The SGR is expected to boost regional integration, alter travel habits, and change Kenyan lifestyles.

RESEARCH METHODOLOGY

The study adopted a non-experimental research design in measuring the freight transport efficiency of standard gauge rail in Kenya. It utilized primary data for the input and output variables for the period, Financial Year 2018/19 to Financial Year 2023/2024 collected from Kenya Railways Corporation. Stochastic Frontier Analysis model was used to estimate the technical efficiency levels of the gauge. The results of the Stochastic Frontier Analysis were further subjected to regression analysis using the Tobit model to determine the factors influencing the technical efficiency of the standard gauge railway transport system in Kenya.

RESEARCH FINDINGS AND DISCUSSIONS

Descriptive statistics evaluated distributive properties of the study variables namely the mean standard deviation, minimum and maximum values. Summary of statistics include absolute values of Key study variables. Trend analysis of natural log of the output variables and key input variables were presented. Table 1 summarized descriptive statistics applied in the study which includes following statistics average (mean), the standard deviation (sd), minimum value (min) and maximum value (max).

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
NTK*	72	205.298	40.962	122.259	283.902
Freight Ton	72	439,408	90476	259,138	616,636
Freight Revenue (KES)*	72	1066.306	230.092	419.819	1387.726
Distance	72	467.818	6.469	451.397	494.55
fuel	72	2616513	615056	1601553	3432400
Inflation rate	72	6.158	1.248	4.53	8.78
Exchange rate	72	116.322	15.873	100.09	160.75

Table 1 presents net tonne kilometres (NTK) and freight revenue estimates in millions. The average monthly revenue during the study period was KES 1.066 billion, with a standard deviation of KES 230 million. NTK represents the weight after factoring in the distance covered by the government during enforcement. The average distance for a typical goods was 467 kilometres, with a standard deviation of 6 kilometres, indicating that most distances are clustered close to the mean. According to Belloti et al. (2012), input variables that directly or indirectly influence efficiency should be included in SFA analysis. As a result, macroeconomic indicators such as inflation and exchange rates were introduced to track price changes in the economy and how they affect the demand side dynamics of goods operations. The average inflation rate was 6.2%, and the USD to KES exchange rate was approximately 116.322.

Inflation and exchange rates have generally maintained a strong upward trend, with inflation rising from around 5% to highs of 9% and the exchange rate rising from KES 100 per USD in the first quarter of 2018 to around KES 160 per USD by 2022. The first two panels show how the inflation and exchange rate trends react to similar shocks. For example, in 2022, the Kenyan economy experienced a sharp increase in inflation, which was mirrored by a sharp increase in the exchange rate during the same period. CBK (2021) reported that lockdown policies implemented during the Covid-19 pandemic resulted in a sharp 42% decrease in imports, which had an unintended positive effect on the trade balance. Furthermore, the aftermath of the pandemic resulted in a significant increase in fuel and food prices, as well as a weakening of the Kenyan shilling. Correlation analysis was conducted and the results presented in Table 2.

Table 2: Correlations Matrix

Variables	NTK	Ton	Revenue	Distance	Fuel	Inflation	Exchange
NTK	1.000						
Ton	0.998	1.000					
Revenue	0.652	0.627	1.000				
Distance	-0.408	-0.460	0.112	1.000			
Fuel	0.901	0.901	0.675	-0.386	1.000		
Inflation	0.733	0.739	0.401	-0.377	0.751	1.000	
Exchange Rate	0.732	0.744	0.377	-0.479	0.751	0.908	1.000

Table 2 show that tonnage is highly correlated with NTK (Net Ton Kilometers) and fuel consumption is expected due to the inherent relationship between these variables in the context of transportation and logistics. It is also important to note that fuel was positively correlated to both inflation and exchange rate confirming that changes in macroeconomic indicators may impact efficiency in cargo transportation. Further analysis was conducted to evaluate the statistical properties of the time series.

Stationarity tests

Stationarity test was conducted using Augmented dickey fuller and Phillip Pherron tests at 5 percent level of significance. Table 3 presents the results.

Table 3: Stationarity Test Results

	Dickey Fuller Test		Phillip-Perrons Test		
	Level	**First Difference**	**Level**	**First Difference**	**Decision**
Ln(revenue)	-3.499***		-3.55***		*I(0)*
Ln(ntk)	-2.461**		-2.161**		*I(0)**
Ln(tonnage)	-2.262**		-2.126		*I(0)**
Ln(Distance)	-3.453**		-3.298**		*I(0)*
Inflation	-1.091	-7.738***	-1.271	-7.867***	*I(1)*
Exchange rate	-0.878	-5.579***	-1.063	-5.511***	*I(1)*

* $p < 0.05$, ** $p < 0.01$, *** *I(0)*** stationary with a drift

Table 3 present the stationarity test for the variables after transforming revenue, tonnage, distance, and NTK into their natural logarithmic form. The results show that the series were either stationary at level or stationary after the first difference, indicating that the series were either integrated of order zero, I(0), or integrated of order one, I(1). Furthermore, the natural log of NTK and the natural log of tonnage and inflation rate were stationary with a drift, while the natural log of revenue was stationary with zero lags. Both inflation and exchange rates were stationary after differencing once. Further analysis indicated that the distance covered suffered from structural breaks. Therefore, the natural log of distance and/or first difference were used for estimation.

Model Estimation

The study utilized Revenue and NTK as measures of efficiency. Revenue is an essential measure of performance for railway freight services because it provides insights into financial health, market competitiveness, and strategic growth potential. While NTK captures operational output, revenue ensures that the output aligns with profitability and financial sustainability. Together, they offer a comprehensive evaluation of performance.

Technical Efficiency

The first objective sought to determine the level of technical efficiency; average technical efficiency was used to address the objective. To address the objective, two stochastic frontier models were estimated. The first model consisted of the natural log of NTK as a dependent variable and the natural log of fuel, the first difference of inflation and the first difference of exchange rate as independent variables. The second model utilized the natural log of revenue as the dependent variable, fitted the natural log of distance, the first difference of inflation and the first difference of exchange rate as dependent variables. This study introduced inflation and the exchange rate as input variables to capture the effects of external macroeconomic factors on the operational efficiency of railway freight operations. These variables provide a more comprehensive understanding of efficiency, cost management, and revenue generation, enabling a more accurate evaluation of the railway service's performance relative to economic condition. Table 4 shows the stochastic frontier model results.

Table 4: Stochastic Frontier Model Results

	NTK	Revenue
Technical Efficiency	0.94***	0.873***
	(22.38)	(8.01)
Natural log of fuel	0.699***	0.614**
	(16.44)	(2.28)
Inflation rate	-0.0873**	-0.0388
	(-2.50)	(-0.77)
Exchange rate	0.0123*	0.0126**
	(1.70)	(2.44)
Natural Log of Distance		8.538
		(0.92)
Constant	8.86***	-40.64
	(14.01)	(-0.67)
Observations	72	72
Sigma (σ_u)	0.0632	0.1461
Sigma (σ_v)	0.0531	0.0542
Lamda (σ_u/σ_v)	1.134	2.69

Table 4 shows that the average technical efficiency for the revenue model is 0.87, indicating that SGR freight services are operating at 87% efficiency relative to the optimal frontier, while the NTK model's average technical efficiency is 0.94, suggesting that SGR freight service is moving freight at 94% efficiency. The higher efficiency in the NTK model compared to the revenue model implies that companies are better at managing freight volume than maximizing revenue. Several factors contribute to the inefficiency of SGR freight movement, including slow container loading and unloading, bureaucratic billing, and inefficiencies in administering taxes and tariffs. Long-term freight agreements (LFTAs) also performed poorly, moving only 20% of the guaranteed tonnage, resulting in an opportunity loss of $5.68 billion. Increasing goods tonnage can lead to economies of scale, reducing costs per ton-kilometer and optimizing the utilization of available transport capacity and infrastructure. SGR Freight should focus on maximizing freight tonnage to boost both physical (NTK) and financial (revenue) efficiency, which aligns with the findings of Martínez-Zarzoso & Nowak-Lehmann (2003). Investing in infrastructure and promoting the LFTA marketing approach can help transport larger freight volumes, increase tonnage capacity and efficiency, and lead to steady demand, allowing for risk reduction, capacity building, and streamlining of logistics and operations, as supported by the studies of Coelli et al. (2005) and Clark & Micco (2004).

Determinants of Technical Efficiency

The second objective sought to identify the determinants of technical efficiency in SGR freight service transportation. To address the objective, the Tobit model was estimated with robust standard errors. The model used the average technical efficiency level (0.95) of the SFA models as the dependent variable. The independent variables included the natural log of fuel cost, the natural log of tonnage, the natural log of distance, the first difference of inflation and the first difference of exchange rate. Table 5 presents the results.

Table 5: Tobit Model Results

	Coeff	**Std Err.**
Natural Log of Revenue	0.41215***	10.04
Natural Log of Tonnage	0.712***	13.83
Natural Log of Distance	0.617***	4.69
Natural Log of fuel	-0.618***	-14.40
Inflation rate: First Difference	0.1015***	10.80
Exchange rate: First Difference	-0.01448***	-8.95
Distance: First Difference	-0.00520**	-2.08
var(e.tefn)	0.000175**	3.10
var(e.tefr)	0.00235***	4.96
Observations	72	72

Table 5 reveals that tonnage positively and significantly affects the technical efficiency of the Standard Gauge Railway (SGR) freight service at the 5% significance level, with a one-unit increase in tonnage raising the chance of improving technical efficiency by 0.712, ceteris paribus. This finding aligns with the studies by Haris & Ridell (2004) and Martínez-Zarzoso & Nowak-Lehmann (2003), which emphasize the importance of maximizing freight volume for improving operational and financial performance. Macroeconomic indicators also play a significant role, with a one-point increase in inflation raising the chance of improving technical efficiency by 0.1015, while a one-point depreciation of the exchange rate reduces it by 0.01448, assuming other factors remain constant. These results are consistent with the findings of Coelli et al. (2005), Fuji & Makino (2001), and Liu & Xu (2015), highlighting the impact of macroeconomic factors on firm performance and technical efficiency. Fuel costs negatively impact efficiency, with a one-point rise increasing the chance of lower technical efficiency by 0.618, all else equal. Distance, using the natural log, suggests that longer distances improve operational efficiency, possibly due to economies of distance and better capacity utilization.

CONCLUSIONS

The study found that SGR freight services operate at high technical efficiency levels, with NTK efficiency (94%) being higher than revenue efficiency (87.3%), indicating better management of freight volume than revenue maximization. Factors contributing to inefficiencies include slow container loading and unloading, bureaucratic delays in billing, inefficiencies in administering taxes and tariffs, and poor performance of long-term freight agreements. The findings also revealed that tonnage, macroeconomic indicators (inflation and exchange rate), fuel costs, and distance significantly impact technical efficiency, highlighting the need for strategies to increase tonnage, reduce fuel costs, and optimize operations based on distance to enhance overall efficiency.

POLICY IMPLICATIONS

The study sought to estimate the technical efficiency of SGR freight services and investigate its determinants. The results showed that the level of technical efficiency was high but could be improved by addressing operational and logistical challenges such as slow container loading and unloading, bureaucratic delays in billing, and inefficiencies in administering taxes and tariffs. The study recommended that SGR management should invest in critical infrastructure, introduce data-driven administration processes, conduct a cost-benefit analysis to revise freight pricing structures, and focus on Long-Term Freight Agreements (LFTAs) marketing strategy to strengthen partnerships with clients and improve revenue efficiency.

REFERENCES

African Development Bank Group. (2020). *Ethiopia-Sudan - Feasibility Study on the proposed Standard Gauge Railway (SGR) connecting The Federal Democratic Republic of Ethiopia and The Sudan.*

African Union. (2023). *Programme for Infrastructure Development in Africa (PIDA): First 10-Year Implementation Report.* file:///C:/Users/Administrator/Downloads/PIDA%20Progress%20Report_WEB.pdf

Aigner, D., Lovell C.A., and Schmidt P., (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics 6: 21- 27.* https://doi.org/10.1016/0304-4076(77)90052-5

Ali, A. I., & Seiford, L. M. (1993). Computational accuracy and infinitesimals in data envelopment analysis. *Information Systems and Operational Research*, 31(4), 290-297. https://doi.org/10.1080/03155986.1993.11732232

Archetti, C., Peirano, L., & Speranza, M. G. (2022). Optimization in multimodal freight transportation problems: A Survey. *European Journal of Operational Research*, *299*(1), 1-20. https://doi.org/10.1016/j.ejor.2021.07.031

Bayane, B. M., Yanjun, Q., & Bekhzad, Y. (2020). A review and analysis of railway transportation system in the economic community of West African States: Towards the development of sustainable regional goal. *Global Journal of Engineering and Technology Advances*, 2(2), 11–22. https://doi.org/10.30574/gjeta.2020.2.2.0004

Bešinović, N. (2020). Resilience in railway transport systems: a literature review and research agenda. *Transport Reviews*, *40*(4), 457-478. https://doi.org/10.1080/01441647.2020.1728419

Bijman, J., Mugwagwa, I., & Trienekens, J. (2020). Typology of contract farming arrangements: a transaction cost perspective. *Agrekon*, *59*(2), 169-187. https://doi.org/10.1080/03031853.2020.1731561

Bouraima, M. B., Alimo, P. K., Agyeman, S., Sumo, P. D., Lartey-Young, G., Ehebrecht, D., & Qiu, Y. (2023). Africa's railway renaissance and sustainability: Current knowledge, challenges, and prospects. *Journal of Transport Geography*, *106*, 103487. https://doi.org/10.1016/j.jtrangeo.2022.103487

Brautigam, D., Bhalaki, V., Deron, L., & Wang, Y. (2022). *How Africa Borrows From China: And Why Mombasa Port is Not Collateral for Kenya's Standard Gauge Railway* (No. 2022/52). Working Paper.

Byiers, B., Medinilla, A., & Karaki, K. (2023). *Navigating green economy and development objectives: The political economy of greening transport in East Africa*. ECDPM Briefing Note 159 (Part 4). Maastricht: ECDPM.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European journal of operational research*, *2*(6), 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

Chege, S. M., Wang, D., Suntu, S. L., & Bishoge, O. K. (2019). Influence of technology transfer on performance and sustainability of standard gauge railway in developing countries. *Technology in Society*, *56*, 79-92. https://doi.org/10.1016/j.techsoc.2018.09.007

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., and Battese, G. E. (2005), An Introduction to Efficiency and Productivity Analysis, 2nd Edition, New York :Springer.

Gachui, M. W. (2020). *Effect of Rail Freight Transportation on Operational Performance of Logistics Firms in Kenya* (Doctoral dissertation, University of Nairobi).

Ghiyasi, M., & Cook, W. D. (2021). Classifying dual role variables in DEA: The case of VRS. *Journal of the Operational Research Society*, *72*(5), 1183-1190. https://doi.org/10.1080/01605682.2020.1790309

Ghoshal, S., & Moran, P. (1996). Bad for practice: A critique of the transaction cost theory. *Academy of management Review*, *21*(1), 13-47.

Githaiga, N. M. (2021). The Successes and Challenges of Kenya‟ s Mombasa-Nairobi Standard Gauge Railway Transport Operations: A Special Reference to the Users.

Greve, H. R., & Argote, L. (2015). Behavioral theories of organization. *International encyclopedia of the social & behavioral sciences*, 481-486.

Haaskjold, H., Andersen, B., Lædre, O., & Aarseth, W. (2020). Factors affecting transaction costs and collaboration in projects. *International Journal of Managing Projects in Business*, *13*(1), 197-230.

Irandu, E. M., & Owilla, H. H. (2020). The economic implications of belt and road initiative in the development of railway transport infrastructure in Africa: The case of the standard gauge railway in Kenya. *The African Review*, *47*(2), 457-480.

Ishikawa, A. (2021). Why does production function take the Cobb–Douglas form?. In *Statistical properties in firms' large-scale data* (pp. 113-135). Singapore: https://doi.org/10.1007/978-981-16-2297-7_9