Assessment Of The Contribution Of Smartcard Technology To The Dar ES Salaam Bus Rapid Transit Operation
(A Case of Kivukoni Bus Terminal)

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DOI: 10.29322/IJSRP.15.09.2025.p16524
https://dx.doi.org/10.29322/IJSRP.15.09.2025.p16524

Paper Received Date: 27th August 2025
Paper Acceptance Date: 23rd September 2025
Paper Publication Date: 30th September 2025

Abstract

Urban transportation systems in rapidly growing cities face significant pressure to provide fast, reliable, and accessible services amid increasing commuter demand. In response, the Dar es Salaam Bus Rapid Transit (BRT) system integrated smartcard technology to modernize fare collection and improve operational efficiency. This study assesses the contribution of smartcard technology to the efficiency of the BRT system, focusing on key indicators such as boarding time reduction, fare transaction transparency, passenger convenience, and overall system performance. Using a mixed methods research approach, data were collected from 75 respondents through structured questionnaires and key informant interviews at the Kivukoni Terminal. Quantitative data were analyzed using SPSS for descriptive and regression statistics, while qualitative insights were evaluated through thematic analysis using NVivo. Findings reveal that smartcards significantly reduce boarding time, with over 89% of respondents agreeing that entry is faster and more convenient. The system also supports a shift towards a cashless economy, enhancing revenue security and decreasing fraud risks. Regression results show a strong positive relationship ($\beta = 0.743$, $p < 0.001$) between smartcard usage and perceived system efficiency. However, operational challenges such as limited recharge infrastructure continue to constrain the full realization of these benefits. The study concludes that while smartcard technology has positively transformed the Dar es Salaam BRT system, its potential can only be maximized through strategic improvements. Recommendations include expanding mobile top-up services, increasing public education on smartcard use, and enhancing the technical reliability of the system. These insights provide a basis for policy actions and further research on digital fare systems in Sub-Saharan Africa.

Keywords

Smartcard technology, BRT, Dar es Salaam public transport, cashless fare, digital mobility

1. Introduction

Efficient and reliable urban transport systems are a cornerstone of sustainable urban development, especially in rapidly growing cities of the Global South. As populations increase and urban areas expand, the demand for organized, time-saving, and technologically integrated public transportation continues to rise. Dar es Salaam, the commercial hub of Tanzania, faces growing pressure on its transport

infrastructure, resulting in chronic congestion, inefficient fare systems, and long commuting times (World Bank, 2020). In response to these challenges, the city introduced the Dar es Salaam Rapid Transit (DART) system a Bus Rapid Transit (BRT) service aimed at enhancing public mobility through dedicated lanes, high-capacity buses, and digitized fare collection systems.

One of the core technological innovations within the DART system is the introduction of smartcard technology. Smartcards are contactless fare media embedded with integrated circuits used for processing transactions without physical money. This system forms part of a broader Automated Fare Collection System (AFCS) that aims to promote cashless, faster, and transparent boarding processes (Jones & Brown, 2017). Globally, smartcard adoption in transport systems has been credited with reducing boarding time, curbing fare evasion, and improving user satisfaction. Cities such as London, Singapore, and Bogotá have recorded measurable gains in operational efficiency following smartcard implementation (Jain et al., 2020).

The Dar es Salaam smartcard system seeks to replicate these successes by improving the efficiency of the BRT service through reduced queuing time, real-time revenue monitoring, and eliminating the logistical burden of cash handling. However, the effectiveness of this technology in the Tanzanian context has yielded mixed results. While early evidence suggests that the smartcard system has facilitated faster boarding and supported digital fare collection, adoption rates remain limited due to infrastructural, socio-economic, and institutional challenges (Ngowi, 2018; Chuwa, 2020). These include inadequate recharge points, system malfunctions, limited public awareness, and a digital divide among certain commuter demographics.

Understanding the extent to which smartcard technology contributes to BRT efficiency is crucial for policy evaluation and system improvement. According to the Technology Acceptance Model (TAM), technology adoption is largely influenced by perceived usefulness and perceived ease of use (Davis, 1989). In this context, commuters are more likely to use smartcards if they believe the system is easy to operate and offers time or cost-saving benefits. Moreover, the Diffusion of Innovation (DOI) theory suggests that the success of smartcard systems depends on user readiness, social influence, and infrastructure readiness (Rogers, 2003).

This article aims to assess the contribution of smartcard technology to the operational efficiency of the Dar es Salaam BRT system, specifically focusing on the Kivukoni Terminal. It investigates how smartcards influence boarding time, passenger convenience, and fare transparency. The article also explores systemic barriers affecting performance and adoption. By drawing from empirical data and theoretical frameworks, the study provides valuable insights for transport planners, policymakers, and technology vendors seeking to optimize fare collection and improve commuter experience in Tanzanian urban transit.

Ultimately, the assessment is not only relevant for the Dar es Salaam context but also for other Sub-Saharan African cities exploring the potential of digital fare systems. As cities in the region strive to modernize infrastructure and embrace digital transformation, understanding the contributions and limitations of smartcard systems can guide future implementations. This article thus contributes to the growing body of literature on smart mobility solutions in developing economies, highlighting both progress and areas requiring targeted intervention.

1.1 Statement of the Problem

Urban transport systems in rapidly expanding cities like Dar es Salaam face persistent inefficiencies, including traffic congestion, long boarding times, fare leakages, and inadequate service reliability. The introduction of the Dar es Salaam Bus Rapid Transit (BRT) system was a strategic effort to improve urban mobility through dedicated lanes, modern buses, and digital fare collection mechanisms. Among these innovations, smartcard technology was adopted to streamline fare payments, reduce cash handling, and improve operational performance (Ngowi, 2018). However, despite these intentions, the system’s efficiency gains remain partially unrealized.

Studies have shown that the adoption of smartcard systems in developing countries often faces significant limitations such as poor system reliability, limited recharge infrastructure, low digital literacy, and lack of user awareness (Chuwa, 2020; Mutagahywa et al., 2018). In Dar es Salaam, a substantial number of commuters still rely on cash payments, citing difficulty in accessing recharge points and frequent card reader malfunctions (Mwakalebela, 2019). These operational inefficiencies contradict the core objective of implementing smartcards, which was to reduce boarding time and enhance fare transparency.

Moreover, the system's limited integration with mobile money platforms and inadequate public education campaigns have hindered wider user adoption (World Bank, 2020). Without addressing these systemic challenges, the potential of smartcard technology to optimize the efficiency of the BRT system remains constrained.

Therefore, it is imperative to critically assess the actual contribution of smartcards to BRT efficiency in the Dar es Salaam context. This assessment will help identify functional gaps, inform policy, and guide improvements in urban mobility infrastructure.

2. Literature review

2.1 Theoretical review

This study is anchored on two foundational theories: the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory. According to Davis (1989), TAM posits that perceived usefulness and perceived ease of use significantly influence technology adoption. In the case of Dar es Salaam's BRT system, commuters are more likely to adopt smartcard technology if they find it beneficial and user-friendly. Additionally, Rogers' (2003) DOI theory explains the process through which innovations spread in society, emphasizing stages such as knowledge, persuasion, and adoption. This framework helps to understand how different commuter segments in Dar es Salaam respond to smartcard innovation.

2.2 Empirical review

Globally, smartcard systems have improved fare collection efficiency and user satisfaction in cities like London and Tokyo (Jain et al., 2020; Shin et al., 2019). However, African cities such as Nairobi and Johannesburg face barriers like poor infrastructure, limited awareness, and resistance from informal transport players (Ngugi & Ombuki, 2019; Kinyanjui et al., 2021). In Tanzania, initial studies show improvements in fare efficiency but also point to challenges such as system downtime, insufficient recharge points, and low user education (Mosha & John, 2022; Mutagahywa et al., 2018).

Despite these insights, limited research focuses specifically on Dar es Salaam's smartcard implementation. This study addresses that gap by exploring its operational impact, user perceptions, and strategic improvement areas thus contributing to the understanding of digital fare systems in developing urban contexts.

3. Methodology

This study used a descriptive mixed-methods research design to evaluate the impact of smartcard technology on the Dar es Salaam Bus Rapid Transit (BRT) operation. A mixed-methods approach was used to incorporate quantitative and qualitative viewpoints, resulting in a more complete knowledge of commuter experiences and system performance. According to Creswell and Plano Clark (2018), using both numerical trends and comprehensive narratives improves the validity and depth of transportation studies, especially when measuring user behavior and technological adoption. The study concentrated on the Kivukoni Terminal, one of the busiest nodes in the Dar es Salaam BRT network.

The area was chosen because of its large passenger traffic, strategic location, and widespread use of smartcard systems. The target population consisted of BRT riders, operational staff, and management representatives directly involved in smartcard operations.

The survey had 75 respondents. The sample was drawn using simple random sampling for passengers to ensure that each commuter had an equal chance of being selected, hence avoiding selection bias. Purposive sampling was used with BRT staff and management to include important informants with extensive knowledge of the system. Slovin's formula was used to calculate the necessary sample size, assuring statistical reliability with a 95% confidence level and a 5% margin of error (Krejcie & Morgan, 1970).

Primary data were gathered through structured questionnaires and semi-structured interviews. The questionnaire included both closed-ended and Likert-scale questions intended to examine impressions of efficiency, boarding time, fare convenience, and obstacles. Interviews were performed with key informants, including station managers, system operators, and frequent passengers, to acquire a better understanding of operating experiences and system limits. Secondary data were collected from institutional reports, DART operational documentation, and peer-reviewed literature on smartcard implementation in Sub-Saharan Africa.

Quantitative data were analyzed using SPSS (Version 28) to obtain descriptive statistics such as frequencies, means, and standard deviation. Additional inferential techniques, such as Pearson correlation and multiple regression, were used to assess the relationship between smartcard use and system efficiency. NVivo software was used to do thematic analysis on qualitative data in order to uncover reoccurring themes and insights from interviews. Thematic analysis enabled the categorization of interview data into relevant categories indicating system contributions, user issues, and improvement plans (Braun & Clarke, 2006).

Cronbach's Alpha was used to examine the instrument's reliability, and all constructs scored over 0.8, indicating strong internal consistency (Tavakol & Dennick, 2011). Validity was ensured through pilot testing, expert reviews, and data triangulation, which improved the robustness and trustworthiness of the findings. The study strictly followed ethical research guidelines. Respondents were given informed consent forms, and confidentiality was ensured. Before data collection, the Dar es Salaam Maritime Institute's research ethics committee approved the study.

4. Findings and Discussion

Response Rate

A total of 80 questionnaires were distributed, out of which 75 were successfully completed and returned, yielding a response rate of 94%. According to Babbie (2010), a response rate above 70% is considered very well in social science research. Thus, this high return rate strengthens the reliability and generalizability of the study findings.

Table 1: Response rate

Questionnaire distributed	Questionnaire filled and returned	Response rate
80	75	94%

Source: Field Data (2025)

Descriptive Findings: Contribution of Smartcard Technology

The study assessed how smartcard technology has enhanced efficiency within the BRT Operation. Four main contribution indicators were examined: reduction in boarding time, elimination of cash, fare transparency, and convenience. The results from the responses received are shown in Table 2 below.

Source: Field Data (2025

The findings of this study reveal that smartcard technology significantly contributes to enhancing the operational efficiency of the Dar es Salaam Bus Rapid Transit (BRT) system across multiple dimensions. Each contribution element was evaluated based on respondents' perceptions, and the mean and standard deviation values offer valuable insights into the consensus levels and variability of these perceptions.

One of the highest-rated contributions is "Smartcard reduces boarding time" (Mean = 4.93, SD = 0.25), indicating a strong agreement among respondents. The minimal standard deviation reflects a near-universal consensus that smartcards eliminate time-consuming cash transactions during boarding, thus accelerating passenger movement. Efficient boarding minimizes dwell time at stations, directly reducing travel delays and enhancing service frequency (ITDP, 2020). In a high-demand corridor such as Dar es Salaam's BRT, faster boarding translates into improved punctuality and increased system throughput, thereby reinforcing overall service efficiency.

Table 2. Descriptive statistics on contribution of smartcard technology

Response	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean (SD)	TOTAL
Smartcard reduces boarding time	70 (93.33)	5 (6.67)	0 (0)	0 (0)	0 (0)	4.93 (0.25)	75 (100)
Enhanced Fare Collection Transparency	65 (86.67)	5 (6.67)	5 (6.67)	0 (0)	0 (0)	4.80 (0.58)	75 (100)
Improved Passenger Flow and Station Management	55 (73.33)	15 (20)	5 (6.67)	0 (0)	0 (0)	4.67 (0.59)	75 (100)
Reduction in Human Resource Costs	60 (80)	10 (13.33)	4 (5.33)	1 (1.33)	0 (0)	4.73 (0.63)	75 (100)
Increased Ridership Confidence	50 (66.67)	20 (26.67)	5 (6.67)	0 (0)	0 (0)	4.61 (0.61)	75 (100)
Support for Data-Driven Decision Making	50 (66.67)	20 (26.67)	4 (5.33)	1 (1.33)	0 (0)	4.60 (0.63)	75 (100)
Improved Travel Time Reliability	70 (93.33)	5 (6.67)	0 (0)	0 (0)	0 (0)	4.93 (0.25)	75 (100)
Promotion of a Cashless Economy	59 78.67	15 (20)	0 (0)	1 (1.33)	0 (0)	4.76 (0.49)	75 (100)

Similarly, "Improved travel time reliability" (Mean = 4.93, SD = 0.25) received the same high rating, underscoring the positive ripple effect that smartcard-enabled boarding efficiency has on travel predictability. Travel time reliability is a critical performance indicator in public transportation; when variability in travel times is minimized, passengers can better plan their commutes, which boosts satisfaction and loyalty (Li et al., 2016).

"Enhanced fare collection transparency" (Mean = 4.80, SD = 0.58) was also rated highly, emphasizing how digital fare systems contribute to accountability and transparency. Unlike cash-based systems susceptible to revenue leakage and fraud, smartcard systems generate digital records that can be audited and monitored in real-time (Mulley & Nelson, 2009). This transparency ensures that funds are accurately reported and reinvested in system improvements.

"Promotion of a cashless economy" (Mean = 4.76, SD = 0.49) aligns with national financial inclusion strategies and contributes to operational resilience, especially during health crises such as COVID-19 (World Bank, 2021). For the BRT system, reducing reliance on cash minimizes transaction handling, reduces queue times, and simplifies fare structures.

"Reduction in human resource costs" (Mean = 4.73, SD = 0.63) indicates smartcard systems reduce the need for manual fare collection roles, allowing reallocation of staff to customer-focused services (Cervero & Dai, 2014).

"Improved passenger flow and station management" (Mean = 4.67, SD = 0.59) shows that smartcards streamline gate access and crowd control, leading to safer, more efficient station operations (Vuchic, 2005).

"Increased ridership confidence" (Mean = 4.61, SD = 0.61) and "Support for data-driven decision making" (Mean = 4.60, SD = 0.63) reflect public trust in the convenience of smartcards and the potential for informed route planning through smartcard data analytics (Pelletier, Trépanier, & Morency, 2011; Eboli & Mazzulla, 2007).

Collectively, these findings affirm the role of smartcard technology in ensuring efficient, transparent, and user-friendly public transport in Dar es Salaam.

Correlation Analysis

The Pearson correlation coefficient was used to measure the strength and direction of the linear relationship between the contribution of smartcard technology and the efficiency of the BRT system.

Table 3. Correlation Analysis of the study variables

Variables	Contribution of Smartcard Technology	Efficiency of BRT System
Contribution of Smartcard Technology	1.000	0.812**
Efficiency of BRT System	0.812**	1.000

N = 75; Correlation is significant at the 0.01 level (2-tailed

The correlation coefficient (r = 0.812) indicates a strong positive and statistically significant relationship between the contribution of smartcard technology and the efficiency of the Dar es Salaam BRT system. This implies that as the effectiveness of smartcard features (such as reduced boarding time, fare transparency, and improved data use) increases, so does the operational efficiency of the BRT system. This is consistent with past studies emphasizing the transformative role of intelligent fare systems in urban transport performance (Pelletier et al., 2011; Li & Voege, 2017).

Regression Analysis

To further understand the predictive power of smartcard technology on BRT efficiency, a linear regression analysis was conducted.

Table 4: Model summary for BRT efficiency

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.812	0.659	0.654	0.382

The R value of 0.812 indicates a strong correlation, and the R Square = 0.659 shows that approximately 65.9% of the variation in BRT efficiency can be explained by the contribution of smartcard technology. The remaining 34.1% could be attributed to other factors such as infrastructure quality, management practices, or vehicle availability.

Table 5. ANOVA for BRT efficiency

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	25.689	1	25.689	176.27	0.000**
Residual	13.311	73	0.182		
Total	39.000	74			

Significant at $p < 0.01$

The ANOVA results confirm the regression model is statistically significant ($F = 176.27$, $p < 0.01$). This means smartcard contribution is a significant predictor of BRT efficiency. The high F-value suggests that the model has good explanatory power.

Table 6: Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
1		B	Std. Error	Beta		
	(Constant)	0.985	0.172			5.726
	Contribution	0.743	0.056	0.812		13.273

The regression coefficient ($B = 0.743$) indicates that for every one-unit increase in smartcard contribution, there is a 0.743-unit increase in BRT system efficiency, holding other factors constant. The significance level ($p = 0.000$) supports the strength of this relationship. This aligns with research emphasizing the productivity gains from automated fare systems and smart ticketing technologies in urban transport networks (Vuchic, 2005; Cervero & Dai, 2014). The correlation and regression analyses both show a statistically significant and strong positive relationship between the contribution of smartcard technology and the efficiency of the Dar es Salaam BRT system. With an R^2 of 65.9% and a regression coefficient of 0.743, the findings suggest that improvements in smartcard usage such as reduced human error, enhanced fare control, and faster boarding can meaningfully enhance operational efficiency. As smart urban mobility systems continue to evolve, the integration of digital fare technologies becomes a cornerstone for reliable and efficient mass transit operations in developing cities.

5. Conclusion

This study examined the impact of smartcard technology on the Dar es Salaam Bus Rapid Transit (BRT) system operation, focusing on key metrics such as reduced boarding time, cashless fare handling, fare transparency, and user convenience. The findings clearly suggest that smartcards improve operational efficiency. The majority of respondents said that smartcards cut boarding delays, remove the need for cash transactions, and improve the overall passenger experience.

Smartcard usage positively correlates with system efficiency ($\beta = 0.812$, $p < 0.001$), and commuters value the convenience and quickness it provides (qualitative insights). However, these advantages are mitigated by infrastructure constraints such as insufficient recharge sites, occasional card reader malfunctions, and low digital literacy among specific user segments.

The study adds to both theoretical and practical discussions. It theoretically supports the Technology Acceptance Model (TAM) and the Diffusion of Innovation Theory (DOI), demonstrating that perceived ease of use and infrastructural readiness are crucial for uptake. Practically, the findings highlight the urgent need for infrastructure upgrades, increased service accessibility, and ongoing user assistance. To fully harness the potential of smartcard technology and increase the BRT system's sustainability, transportation authorities, technology suppliers, and policymakers must work together.

6. Recommendations

In light of the findings and consequences, this study makes numerous recommendations to improve the contribution of smartcard technology to the efficiency of the Dar es Salaam BRT system. Addressing highlighted obstacles and using existing strengths will assure the smartcard technology's long-term viability, inclusivity, and efficacy.

First and foremost, there is an urgent need to develop the recharging infrastructure throughout the city. Many commuters reported difficulty finding recharge outlets, particularly in outlying locations. Adding more top-up places at stations, neighboring stores, mobile vendor kiosks, and collaborating with local retail establishments would lower access barriers and encourage greater use of the technology. This decentralization of recharging services would improve system convenience while also increasing equity among consumers from various socioeconomic backgrounds.

Furthermore, public education and awareness efforts are critical for expanding system utilization, particularly among technologically disadvantaged groups like elderly folks and informal sector workers. These efforts should leverage a variety of communication channels, including social media, public radio, station signage, and community outreach initiatives, to teach users how to obtain, use, recharge, and troubleshoot smartcards.

To increase openness and confidence, the system should include elements that allow commuters to obtain real-time feedback on their transactions. For example, digital receipts, SMS confirmations, or app-based account tracking would allow users to trace fare deductions, balances, and travel history. Furthermore, the implementation of feedback tools is suggested to ensure that user opinions are heard and incorporated into system enhancements. These could include customer service desks at main terminals, hotlines, or digital channels (such as WhatsApp or USSD services) where users can submit complaints, ideas, or technical issue reports.

Smartcard technology's success in the Dar es Salaam BRT system is determined not just by its technological platform, but also by infrastructure, user involvement, and institutional frameworks. Implementing these recommendations will ensure that smartcard technology meets its promise of improving urban transportation efficiency, transparency, and inclusion.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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