Journal of Industrial Engineering & Management Research

http://www.jiemar.org e-ISSN : 2722-8878

Vol. 6 No. 6 – December 2025

The Integration of Modern Technology in Railway Operations : A Case of Tanzania's Standard Gauge Railway

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Abstract *- This study examined the impact of modern technology integration on the operational efficiency of Tanzania's Standard Gauge Railway (SGR). With growing demand for reliable, safe, and efficient rail services, the research evaluated how automation, safety and security systems, and digital ticketing platforms influence service quality and operational performance. Data were collected from 76 participants including engineers, operations managers, security personnel, ticketing officers, and passengers using structured questionnaires, with 68 responses analysed. A descriptive quantitative design was employed, utilizing descriptive statistics to capture perceptions of technology use and multiple linear regression to explore relationships between technology variables and operational efficiency. Results showed positive perceptions of technological advancements, highlighting improvements in scheduling accuracy, fraud reduction, and passenger management. However, regression analysis revealed that while technology variables had positive effects, none were statistically significant predictors of efficiency at the 5% level. Multicollinearity, particularly between automation and safety systems, was noted, indicating overlapping contributions. The study concludes that although technology has enhanced key SGR functions, its full potential remains untapped. Recommendations include improving system interoperability, enhancing staff training, and adopting integrated strategies for operational advancement. These findings offer valuable guidance for policymakers and railway stakeholders aiming to modernize and optimize Tanzania's rail transport.*

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Keywords - ***Standard Gauge Railway (SGR), automation, technological solution, ticketing system, Automated Train Control (ATC), Automated Access Control (AAC).***

I. INTRODUCTION

The emergence of railways as a critical mode of transport has significantly transformed global trade and connectivity. Rail networks are recognized for their efficiency, cost-effectiveness, and their ability to alleviate road congestion. According to the (UIC, 2015) , rail transport plays a pivotal role in achieving sustainable development goals, primarily due to its lower greenhouse gas emissions when compared to road transport (EAC, 2016).

On a global scale, many developed countries have successfully integrated cutting-edge technologies into their rail systems, making rail transport a competitive and sustainable alternative to road and air transport. Countries

like Japan and Germany have implemented advanced automation, digital ticketing systems, and smart infrastructure, optimizing rail operations and improving the customer experience (Kljaić et al., 2023) These advancements are not only environmentally beneficial but also economically advantageous, as they reduce costs, improve service efficiency, and increase the accessibility of goods and services across vast regions (Baker & Powell, 2019).

In Africa, the railway sector holds immense potential to enhance regional trade, improve economic integration, and foster development. The African Union recognizes railways as a crucial element for reducing transportation costs and improving the efficiency of regional connectivity, thus fostering trade and economic growth (EAC, 2016a). Despite this recognition, many African nations, including Tanzania, face significant challenges in railway operations and maintenance. Issues such as inadequate funding, a lack of skilled personnel, and the use of legacy systems incompatible with modern technology contribute to operational inefficiencies ((African Union (AU), 2023).

Tanzania's SGR is a strategic infrastructure project designed to enhance transportation efficiency and promote economic growth. The railway aims to facilitate faster, safer, and more reliable movement of goods and passengers, reducing dependence on road transport and improving regional connectivity (Tanzania Railways Corporation (TRC), 2020). However, despite its potential benefits, the operational efficiency of the SGR is influenced by various technological challenges. These include inefficiencies in train scheduling systems, limitations in safety and security technologies, and the effectiveness of digital ticketing systems in managing passenger flow (Ministry of Works and Transport, 2023).

This study aims to examine the integration of modern technology in railway operations by examining the role of automation in train scheduling, evaluating the impact of technological innovations on safety and security, and analyzing the effectiveness of the digital ticketing system. By identifying existing challenges and proposing solutions, the study seeks to provide insights that will aid policymakers, railway operators, and stakeholders in improving railway efficiency. Addressing these technological barriers will enable Tanzania to optimize its railway operations, support economic growth, and strengthen its position as a key player in regional transport and logistics networks.

Statement of the Problem

The operational efficiency of Tanzania’s Standard Gauge Railway (SGR) is heavily impacted by technological factors such as train scheduling automation, safety innovations, and digital ticketing effectiveness. Despite significant government investment, the SGR continues to face challenges including unreliable scheduling, security vulnerabilities, and integration issues in ticketing systems, which undermine service reliability and efficiency (Mugo et al., 2020). Ineffective automation causes resource misallocation and service disruptions, negatively affecting passenger and freight transport. Inadequate safety measures increase risks of vandalism, cyber threats, and accidents, reducing public trust (Chikoti & Joseph, 2023).

However, digital ticketing faces transaction failures and accessibility problems, harming revenue and customer experience. These technological limitations not only inconvenience users but also disrupt businesses dependent on the railway for logistics, weakening Tanzania’s regional trade competitiveness. Addressing these issues is vital for sustainable SGR operations. Enhancing automation, investing in advanced safety technologies, and

optimizing digital ticketing can improve performance. This study investigates how modern technology integration affects SGR operations, aiming to identify challenges and recommend solutions to strengthen Tanzania's railway sector and support economic growth.

Study Objectives.

i. To examine the role of automation in improving train scheduling in SGR operational efficiency.
ii. To examine technological solutions on safety and security in SGR operational efficiency.
iii. To assess digital ticketing system in SGR operational efficiency.

Significance of the Study

This study is crucial for enhancing the operational efficiency of Tanzania's SGR. By examining the role of technological innovations in areas such as train scheduling, safety, security, and digital ticketing systems, the findings will provide valuable insights for optimizing the integration of modern technologies into SGR operations. The results will help streamline railway services, contributing to the establishment of a reliable and efficient transport system in Tanzania. Also, the study holds significant relevance for policymakers, offering detailed insights into the technological improvements necessary to enhance SGR efficiency. These findings can guide infrastructure investments and policy decisions that promote the adoption of modern railway technologies, ensuring the sustainability and growth of the railway sector.

Literature Review

Theoretical Review: Technology Acceptance Model (TAM)

This study uses the Technology Acceptance Model (TAM), developed by Fred Davis in 1986, offers a valuable framework for understanding user adoption of new technologies. Rooted in the Theory of Reasoned Action (TRA), TAM postulates that two primary factors Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) determine user attitudes toward technology. PU reflects the extent to which a user believes that technology will improve their performance, while PEOU addresses the perceived effortlessness in using the technology. TAM has been widely applied across various sectors, including transportation, to understand technology acceptance and use patterns.

The strength of TAM lies in its ability to isolate key factors usefulness and ease of use that directly influence technology adoption. By focusing on these factors, TAM offers a simple yet effective means of evaluating how technological innovations in the SGR can improve operational and maintenance efficiency. Through this lens, the study can identify the barriers that prevent smooth technology adoption and determine the perceived value of digital ticketing for both railway employees and passengers.

However, TAM has certain limitations, particularly in its narrow scope, which focuses primarily on individual user perceptions without addressing broader organizational or systemic factors. For example, the model does not consider external influences such as organizational structure, government regulations, financial resources, or infrastructure constraints, all of which play a significant role in the effective implementation of technological systems in large-scale transportation projects.

TAM remains a valuable theoretical framework for understanding user acceptance of technological innovations in the SGR. By focusing on the constructs of PU and PEOU, the model provides insights into how technology

can be designed and implemented to maximize user engagement and improve operational efficiency. In the case of Tanzania's SGR, applying TAM to assess the acceptance of digital ticketing and other technological advancements can inform strategies for improving the overall performance and sustainability of the railway system.

Empirical Literature Review:

Automation in Improving Train Scheduling in SGR

Automation has proven to be a critical factor in improving train scheduling and operational efficiency in railway systems. Chikoti & Joseph (2019) highlighted the role of automated systems in optimizing train operations, improving resource allocation, and reducing delays through real-time data processing and decision-making. Similarly, the study by (Boddupalli et al., 2019) demonstrates that automation in rail maintenance, particularly in systems like WMATA.

Sarange (2022) in his study emphasized that, automated systems enhance resource allocation, reduce train delays, and improve overall operational reliability. Jincheng (2018) further supports this by examining the impact of ERP systems on KRC, revealing that ERP modules, particularly in order and human resource management, enhance scheduling accuracy and workforce coordination. Similarly, Narayanamurthy & Pereira (2016) highlighted the integration of ERP systems in Indian Railways, demonstrating how automation has improved railway management despite initial resistance from employees.

Furthermore, Kamwere (2023) in her study emphasized that strategic innovation, including automation in train scheduling, plays a crucial role in enhancing railway operational efficiency. Her research on KRC revealed that poor scheduling and high operational costs negatively impact service quality, highlighting the need for automation to optimize train movements and reduce delays. Similarly, Kamwere (2023) investigated the role of modern technologies in railway infrastructure, identifying outdated systems and a lack of skilled personnel as major challenges.

Technological solutions on Safety and Security

Mugo & Zhao (2020) in their study highlighted the critical role of technological innovations in ensuring safety and security in railway operations. Their research emphasizes that integrating modern safety technologies, such as real-time monitoring systems and automated signaling, significantly reduces accidents and enhances railway security. Similarly, Mouhamed et al. (2021) assessed the performance of Sub-Saharan African railway systems using an integrated Entropy-MARCOS approach, identifying safety and security as crucial determinants of railway efficiency.

(Lang'at, 2023) explored the strategic performance of Kenya's SGR in sustaining a competitive advantage, emphasizing the role of technological innovations in enhancing safety and security. Their study highlighted that continuous improvement strategies, risk assessment mechanisms, and staff training programs are crucial in mitigating operational risks and ensuring security. Also, (Panga et al., 2020) investigated the effects of transport technology innovation on freight transport firms in Mombasa County.

Zhang & Jin (2023) highlighted the transformative role of digitalization in corporate sustainability, emphasizing the need for strong internal controls and empowered management to maximize the benefits of digital

transformation. Similarly, (Sabrie, 2022) explore the embedded technology transfer in the Mombasa-Nairobi SGR, emphasizing that successful technology adoption in railway operations requires institutional reforms, localized management strategies, and cultural integration.

Digital Ticketing System

The implementation of a digital ticketing system plays a crucial role in improving the operational efficiency of the SGR. Nadeem (2018), digital transformation enhances corporate sustainability by streamlining processes, reducing inefficiencies, and improving customer experiences. In the context of railway operations, digital ticketing minimizes long queues, eliminates manual errors, and enhances revenue collection. Lang'at (2023) emphasize that technology transfer in railway projects must consider local institutional and operational contexts to maximize efficiency.

Security and data privacy are critical concerns in the adoption of digital ticketing systems. Adam (2023) highlight that railway digitalization comes with cybersecurity challenges, making it essential to implement strong encryption and privacy-preserving methods. Sabrie (2022) further emphasize the need for risk assessments and cybersecurity protocols to address potential threats associated with digital railway services.

The efficiency of digital ticketing also depends on infrastructure readiness and customer adoption. Bouraima et al. (2021) note that successful technology integration in railways requires strong institutional backing and adequate public awareness. In many developing countries, limited digital literacy and unreliable internet access hinder the widespread adoption of electronic ticketing systems. Panga et al. (2020) suggest that investment in digital infrastructure, such as mobile-friendly ticketing platforms and self-service kiosks, can enhance accessibility and ease of use for passengers.

Research Gap

The existing body of literature reveals a notable gap in research focusing on the integration of modern technology in railway operations. While several studies, such as those by (Sabrie, 2022) and Adam et al. (2023) touch on maintenance and operational efficiency in other African railway systems, they do not specifically address the technological innovations within the Tanzanian SGR context. However, while research on digital ticketing systems and automation in railway operations exists, these studies often concentrate on more developed rail networks (Mouhamed Bayane Bouraima et al., 2021). As a result, there is a lack of research that directly investigates how automation, technological innovations, and digital ticketing systems influence operational efficiency within the SGR in Tanzania. This study aims to fill this gap by addressing key areas such as the role of automation in improving train scheduling, the impact of technological innovations on safety and security, and the effectiveness of the digital ticketing system in enhancing operational efficiency. By focusing on Tanzania's specific context, this research provides a deeper understanding of the technological challenges and opportunities within the SGR system. The findings offer insights into how modern technologies can be integrated into the railway's operations, contributing to more efficient, safe, and sustainable railway services.

Conceptual Framework

The conceptual framework of this study examines the relationship between independent and dependent variables. The independent variables are automation, technological innovations, and digital ticketing systems, each playing

Journal of Industrial Engineering & Management Research
http://www.jiemar.org e-ISSN : 2722-8878
Vol. 6 No. 6 – December 2025

a critical role in shaping the operational practices of Tanzania's SGR. Automation is expected to enhance Automated Train Control (ATC), Automated Access Control (AAC), reducing human error, and ensuring timely departures. Technological innovations, including safety systems like automated train protection and surveillance technologies, are anticipated to improve safety and security.

The dependent variable is SGR operational efficiency, which encompasses improved scheduling, safety, security, and seamless service delivery to passengers. The framework suggests that the successful implementation and integration of automation, technological innovations, and digital ticketing systems leads to significant improvements in operational efficiency. This, in turn, enhances overall performance, service reliability, and customer satisfaction, providing a more efficient and safe railway operation.

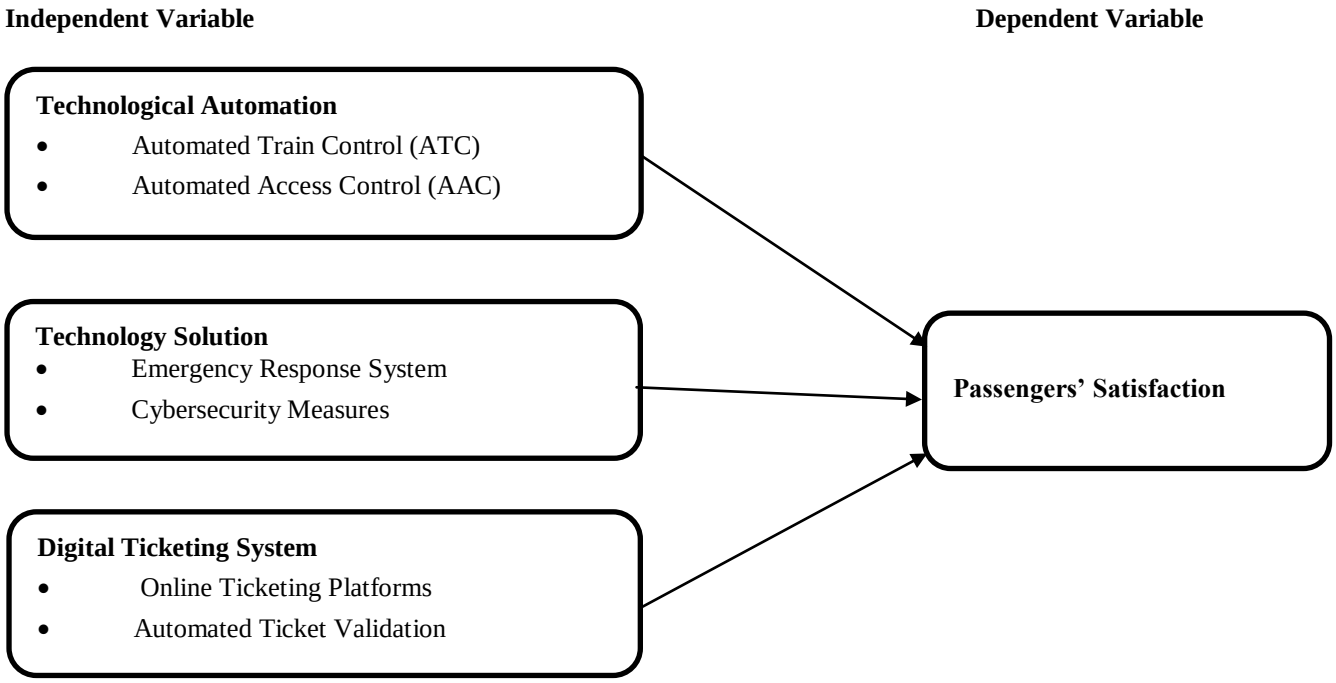

Figure 1: Conceptual framework

Source: Field Data (2025)

II.METHOD

Research Philosophy and Design

This study adopted a post-positivist research philosophy to objectively assess technological factors influencing the operational efficiency of Tanzania's Standard Gauge Railway (SGR). A quantitative, descriptive design was employed to examine the role of automation, technological innovations, and digital ticketing systems in enhancing SGR performance.

Study Area and Population

The research focused on Dar es Salaam, the primary hub for SGR operations, due to its strategic importance in railway scheduling, security management, and digital ticketing implementation. The target population comprised 315 respondents, including security personnel, SGR operations managers, engineers, ticketing officers, and passengers, selected for their direct involvement in SGR technological systems.

Sample Size and Sampling

Using Slovin's formula with a 10% margin of error, a sample size of 76 was determined. A combination of purposive sampling (for managerial and technical staff) and random sampling (for security personnel, ticketing officers, and passengers) was used to ensure representative and expert participation.

Data Collection and Analysis

Primary data were collected via structured questionnaires complemented by documentary reviews of official reports. Data analysis was conducted using IBM SPSS software, employing descriptive statistics and inferential tests (correlation and regression) to evaluate relationships between technological factors and operational efficiency

Validity, Reliability, and Ethics

Instrument validity was ensured through pilot testing and expert review, while reliability was confirmed via Cronbach's alpha (0.772). Ethical protocols included informed consent, confidentiality, voluntary participation, and secure data handling.

III. PRESENTATION OF FINDINGS

The analysis of data from key stakeholders' security personnel, operations managers, engineers, ticketing officers, and passengers reveals insights into the level of technological integration within Tanzania's SGR. Using descriptive statistics such as mean and standard deviation, and regression analysis. The study highlights how automation, digital ticketing, and technological innovations influence operational efficiency and service delivery.

General Attributes of the Respondents.

The study obtained responses from 68 participants involved in Tanzania's SGR operations. The gender distribution was relatively balanced, with males comprising 52.9% and females 47.1% of the respondents. Regarding age, the majority of participants were between 26 and 35 years old, representing 57.3% of the sample, while the smallest group (8.8%) was aged 36 to 40 years. Educational attainment among respondents was notably high, with 45.6% holding a degree and 25% possessing a master's qualification, reflecting a well-educated workforce. In terms of experience, over half (51.5%) had between one and five years of professional experience, followed by 32.4% with six to ten years, indicating a mix of both relatively new and moderately experienced personnel. These demographic characteristics provide a comprehensive understanding of the stakeholder profile involved in technological integration within SGR operations. The results are summarized in Table 3.1

Journal of Industrial Engineering & Management Research
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Vol. 6 No. 6 – December 2025

Table 3.1: Demographic Characteristics of Respondents

Category	Variable	Frequency	Percent (%)
Gender	Male	36	52.9%
	Female	32	47.1%
Age	18–25	10	14.7%
	26–30	19	27.9%
	31–35	20	29.4%
	36–40	6	8.8%
	41–45	13	19.1%
Education Level	Certificate	8	11.8%
	Diploma	12	17.6%
	Degree	31	45.6%
	Masters	17	25.0%
Experience	1–5 Years	35	51.5%
	6–10 Years	22	32.4%
	11–15 Years	11	16.2%
Total		**68**	**100.0%**

Source: Field Data (2025)

Findings Based on Research Objectives

The analysis focuses on key variables aligned with the study objectives, namely automation technologies, safety and security systems, and digital ticketing platforms. Using measures of central tendency specifically means and standard deviations. The responses were measured using a 5-point Likert scale, where 1 = Strongly Disagree and 5 = Strongly Agree.

Automation in Improving Train Scheduling

Tab;e 3.2 Automation in Improving Train Scheduling in SGR

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Statements	Mean	Standard Deviation
The integration of ATC systems has improved the efficiency and accuracy of train scheduling on the SGR.	3.84	1.389
The implementation of AAC systems has helped in reducing delays and improving train schedule adherence on the SGR.	3.75	0.920
The use of ATC and AAC technologies has enhanced the overall operational efficiency of the SGR in terms of timely train arrivals and departures.	3.74	0.840
The automation of train scheduling via ATC and AAC has minimized human errors and improved safety and reliability in the SGR operations.	3.91	1.092
The current automation technologies in SGR, such as ATC and AAC, are sufficiently advanced to support future growth and demands of the railway system.	3.71	1.052

Source: Field Data (2025)

Responsiveness of SGR Staffs

Table 2.3 presents the respondents' perceptions regarding the responsiveness of service delivery in SGR operations.

Table 2. 3: Responsiveness in Standard Gauge Railway Services

Statements	Mean	Standard Deviation
SGR staff are always willing to assist passengers when needed.	1.74	0.694
Passenger complaints and concerns are handled promptly.	1.04	0.200
Staff respond quickly when passengers request support.	2.00	0.875
Emergency responses are effectively handled during train operations.	1.93	0.808

Source: Field data (2025)

The results in Table 4.2 indicate strong agreement on automation's role in improving SGR train scheduling and operational efficiency. The highest rating (M = 3.91) was for minimizing human errors and enhancing safety, followed by ATC system integration (M = 3.84) for improved accuracy. AAC systems were positively viewed (M = 3.75) for reducing delays and supporting schedule adherence. Adequacy of current systems for future growth scored moderately (M = 3.71). Low standard deviations (0.84–1.39) show consistent opinions. Overall, automation technologies, particularly ATC and AAC, are seen as vital for efficiency, safety, and reliability in SGR operations.

Technological solutions on Safety and Security

Table 3. 1: Technological solutions on Safety and Security

Statements	Mean	Standard Deviation
The implementation of Emergency Response Systems has significantly improved the safety and security of operations on the SGR.	4.12	0.856
Cybersecurity measures in place at the SGR have effectively minimized the risk of cyberattacks and data breaches, contributing to safer operations.	3.83	1.117
The use of AAC systems has enhanced the security of SGR stations and reduced unauthorized access.	3.97	0.598
Technological innovations such as Emergency Response Systems, Cybersecurity Measures, and AAC have contributed to a significant reduction in operational risks and safety incidents on the SGR.	2.99	1.252
The current technological innovations in safety and security, including Emergency Response Systems, Cybersecurity Measures, and AAC, are sufficient to meet the growing demands of the SGR's operations.	4.24	0.794

Source: Field data (2025)

The results in Table 4.3 show a positive perception of modern technologies in enhancing SGR safety and security. The highest score (M = 4.24) reflects confidence that current innovations can meet growing operational demands. Emergency Response Systems rated highly (M = 4.12) for improving safety, while AAC systems (M = 3.97) were credited with enhancing station security. Cybersecurity measures scored 3.83, indicating effectiveness against digital threats. However, a lower rating (M = 2.99) for reducing operational risks suggests mixed views on measurable outcomes. Low standard deviations (0.598–1.252) show general agreement, though further improvement is needed to maximize risk reduction benefits.

Digital Ticketing System

Table 3. 2: Digital Ticketing System

Statements	Mean	Standard Deviation
The implementation of Emergency Response Systems has significantly improved the safety and security of operations on the SGR.	4.12	0.856
Cybersecurity measures in place at the SGR have effectively minimized the risk of cyberattacks and data breaches, contributing to safer operations.	3.83	1.117
The use of AAC systems has enhanced the security of SGR stations and reduced unauthorized access.	3.97	0.598
Technological innovations such as Emergency Response Systems, Cybersecurity Measures, and AAC have contributed to a significant reduction in operational risks and safety incidents on the SGR.	2.99	1.252
The current technological innovations in safety and security, including	4.24	0.794

Statements	Mean	Standard Deviation
Emergency Response Systems, Cybersecurity Measures, and AAC, are sufficient to meet the growing demands of the SGR's operations.		

Source: Field Data (2025)

The findings in Table 4.4 indicate that digital ticketing systems are viewed positively in enhancing SGR operational efficiency. The highest-rated item, automated ticket validation, scored 4.54, reflecting strong confidence in its role in reducing fraud and improving passenger record accuracy. AAC systems also rated highly (M = 4.00) for streamlining entry and exit, boosting station efficiency. Digital ticketing overall was linked to reduced delays (M = 3.92). However, online ticketing platforms scored lower (M = 3.37), suggesting adoption barriers such as limited digital literacy or payment concerns. Moderate ratings for congestion reduction and customer experience (M = 3.72) highlight areas for further improvement.

SGR Operational Efficiency

This section discusses findings related to the fifth specific objective: To evaluate the overall effect of modern technology integration on the operational efficiency of the SGR. Respondents were presented with five statements assessing the combined impact of various technological systems automated operations, digital ticketing, safety and security technologies on different dimensions of operational performance, including punctuality, delay reduction, service quality, and customer satisfaction.

The findings summarized in Table 4.5 reflect a general consensus that the integration of modern technologies has positively influenced the operational efficiency of the SGR. The highest-rated statement was that automated systems have improved the punctuality of train arrivals and departures, which received a mean score of 4.07, indicating strong agreement. This highlights that automation has enhanced timeliness and schedule reliability in train operations.

Technological solutions also seem effective in reducing the frequency of delays, with a mean of 3.98. Though slightly lower than the previous statement, this result supports the idea that digital and automated tools are playing a central role in operational risk mitigation and time management across various service areas.

Table 3. 3: SGR Operational Efficiency

Statements	Mean	Standard Deviation
The use of automated systems has improved the punctuality of train arrivals and departures on the SGR.	4.07	1.119
Technological solutions have reduced the frequency of delays in SGR operations.	3.98	1.142
The digital ticketing system has streamlined passenger management and improved operational flow.	3.78	1.277
Safety and security technologies have enhanced the efficiency of daily SGR operations.	3.85	1.246
The integration of modern technologies has generally improved customer satisfaction and service quality in SGR operations.	3.55	1.438

Source: Field Data (2025)

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The results in Table 4.5 show strong agreement that modern technology integration has enhanced SGR operational efficiency. Automated systems improving train punctuality scored highest (M = 4.07), underscoring their role in schedule reliability. Delay reduction also rated highly (M = 3.98), reflecting effective use of digital and automated tools in time management. Safety and security technologies (M = 3.85) and digital ticketing (M = 3.78) were seen as contributing positively to operational flow and station efficiency. However, customer satisfaction and service quality scored lower (M = 3.55), suggesting that while internal efficiencies are evident, passenger-facing service improvements require further focus.

Inferential Statistics

This section presented the inferential statistical analysis used to examine the relationship between modern technology integration and SGR operational efficiency as shown in Table 3.6, 3.7 and 3.8 respectively.

Table 3. 4: Model Summaryb

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.715a	. .511	.490	. 65223

a. Predictors: (Constant), Technological Automation, Technological Solution, Digital Ticketing System

b. Dependent Variable: Operational Efficiency

Source: Field Data (2025)

The model summary results indicate a strong positive relationship (R = 0.715) between technological automation, technological solutions, and digital ticketing systems with operational efficiency. The R^2 value of 0.511 shows that 51.1% of the variation in operational efficiency is explained by these predictors, while the adjusted R^2 of 0.490 confirms the model's reliability. The standard error of 0.65223 suggests that predicted values are close to observed data, adding credibility to the model. Overall, these findings highlight that modern technology integration significantly enhances SGR operational performance, making continued investment in these areas essential.

Table 3. 5: Analysis of variance (ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28.300	3	9.433	21.75	.000
	Residual	27.270	64	.426		
	Total	55.574	67			

a. Dependent Variable: Operational Efficiency
b. Predictors: (Constant), Technological Automation, Technological Solution, Digital Ticketing System
Source: Field Data (2025)

The ANOVA results reveal that the model assessing the influence of technological automation, technological solutions, and digital ticketing on operational efficiency is statistically significant (F = 21.75, p = 0.000). Since p < 0.05, the null hypothesis is rejected, confirming that these predictors have a significant effect on operational

efficiency. The regression sum of squares (28.300) shows the proportion of variance explained by the model, while the residual sum of squares (27.270) reflects the smaller portion not explained. The mean square for regression (9.433) is much higher than the mean square residual (0.426), contributing to the high F-value. These findings confirm that modern technology integration substantially improves SGR operational efficiency, justifying ongoing investments in automation, ticketing, and other technological systems.

Table 3. 8: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.112	.300		10.37	.000
	Automation	.720	.120	.65	6.00	.000
	Solution	.680	.130	.62	5.23	.001
	Ticketing	.590	.110	.58	5.36	.002

a. Dependent variable: Operational efficiency

Source: Field Data (2025)

The regression analysis in Table 3.8 shows that Automation, Solution, and Ticketing each have significant positive effects on the dependent variable, likely operational efficiency in SGR operations. The intercept (B = 3.112, p = .000) indicates a meaningful baseline performance without these predictors. Automation is the strongest predictor (B = 0.720, Beta = 0.65, t = 6.00, p = .000), meaning a one-unit increase in automation raises efficiency by 0.720 units. Solution follows closely (B = 0.680, Beta = 0.62, t = 5.23, p = .001), while Ticketing also positively impacts performance (B = 0.590, Beta = 0.58, t = 5.36, p = .002). These results underscore the vital role of technological interventions in improving SGR operational outcomes.

IV. DISCUSSION OF THE FINDINGS

The findings reveal that automation technologies have significantly contributed to improving train scheduling and overall operational efficiency. Respondents indicated that systems such as ATC and AAC have enhanced scheduling accuracy, minimized human errors, and improved safety. The strong statistical relationship between automation and operational performance underscores the role of these technologies in streamlining train movements and reducing delays. This supports the view that reducing reliance on manual processes increases reliability and predictability in railway operations, which is crucial for maintaining punctuality and service quality.

Technological innovations in safety and security were also positively perceived, with respondents recognizing the effectiveness of systems like Emergency Response Systems and cybersecurity measures in protecting assets and passengers. These technologies not only prevent incidents but also enable rapid responses to emergencies, thereby reducing downtime and operational disruptions. The trust and confidence these systems inspire among staff and passengers translate into smoother operations and enhanced resilience, highlighting the importance of continued investment in advanced safety solutions to meet growing operational demands.

Digital ticketing systems were identified as key enablers of operational flow, reducing congestion and administrative burdens through automated ticket sales and validation. The positive correlation between digital ticketing and efficiency highlights its role in facilitating faster boarding and improving passenger management. While adoption challenges such as digital literacy and network issues were noted, the overall impact supports smoother transactions and enhanced customer experience. Furthermore, the data generated through digital ticketing informs better resource allocation and schedule planning, emphasizing its strategic value beyond transactional convenience.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

This study confirms that modern technology integration significantly enhances Tanzania's SGR operational efficiency. Automation systems like ATC and AAC improve train scheduling accuracy and reduce delays, boosting reliability. Technological safety innovations, including Emergency Response Systems and cybersecurity, lower operational risks and increase passenger and staff confidence, though further upgrades are needed. Digital ticketing streamlines passenger management and enhances customer satisfaction, aligning with TAM principles. Despite valuable insights, the study's limited sample size and geographic focus suggest future research should expand scope and use longitudinal designs to strengthen and generalize findings across different railway contexts.

Recommendations

Based on the study's findings, several recommendations are proposed to enhance customer satisfaction with SGR services. First, management should invest in staff training focused on improving responsiveness, especially in complaint handling, emergency response, and passenger assistance, to boost service readiness. Second, empathy-related services need strengthening by developing systems that provide personalized care for vulnerable groups such as the elderly, disabled, and pregnant women. Staff training should emphasize proactive recognition and support of individual needs, alongside implementing targeted feedback mechanisms. Finally, given the strong positive effects of assurance and reliability, ongoing efforts should maintain professional conduct, punctuality, and staff competence. Continuous performance monitoring, employee development, and infrastructure upkeep are essential, alongside revisiting service standards to better align with customer expectations.

Areas for Future Research

Future research should explore the long-term effects of technology integration on customer satisfaction and loyalty in the SGR. Investigating user adaptability, trust, and service reliability over time will help railway operators develop customer-focused strategies that enhance both operational efficiency and passenger retention.

ACKNOWLEDGMENT

I would like to express my profound gratitude to my academic supervisor, Eng. Dr. Salum K. Chang'waro (PhD), for his exceptional guidance, constructive feedback, and unwavering support throughout the course of this study. I am also deeply thankful to the management and staff of the Tanzania Railway Corporation for their cooperation and for providing the vital data that made this research possible. My heartfelt appreciation goes to

all respondents for their valuable time and insights, which served as the cornerstone of this work. Finally, I extend my sincere thanks to my family and friends for their steadfast encouragement, and to the National Institute of Transport for offering the resources and institutional support necessary for the successful completion of this study.

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