

Leveraging Technology-Driven Logistics for Digital Trade Efficiency in RWANDA

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ABSTRACT

Technology-enabled logistics is increasingly recognized as a catalyst for trade competitiveness, especially within the African Continental Free Trade Area (AfCFTA) framework. This paper investigates the role of technology-driven logistics in facilitating Rwanda's participation in regional and international trade, drawing on empirical findings from the Adventist Development and Relief Agency (ADRA), Rwanda. Results indicate a strong reliance on basic technologies in warehouse management and tracking, with 100% of respondents using barcode scanners as the primary tool. By contrast advanced systems remain underutilized. As highlighted, 83.33% of respondents reported minimal use of RFID, 88.89% reported minimal use of GPS-enabled tracking, and 60.19% reported minimal use of cloud-based inventory management. In planning and forecasting, predictive analytics is the most widely adopted as indicated by 88.89%, but transformative solutions like blockchain, IoT, and big data analytics remain largely untapped. Fulfilment and distribution processes showed moderate use of Transport Management Systems (76.85%), real-time tracking with IoT (71.30%), and mobile technologies (77.78%), whereas robotics, automation, and drone deliveries were scarcely used. The analysis further identifies high investment and implementation costs with 86.11% ranking it as the top barrier. Budget constraints, and integration challenges were identified as critical obstacles to wider technology adoption, while regulatory constraints and data security concerns were not tapped as significant. By connecting these operational realities to Rwanda's trade ambitions, the study underscores how limited adoption of advanced logistics technologies constrains trade efficiency and market integration under AfCFTA. The paper concludes that addressing cost barriers, enhancing digital infrastructure, and fostering interoperability across African markets are essential steps to enhance Rwanda's trade competitiveness and fully realize the benefits of regional and international trade.

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KEYWORDS: Digital trade, logistics, supply chain management, AfCFTA, Rwanda, technology adoption, trade efficiency.

INTRODUCTION

Digital transformation is redefining the dynamics of global trade logistics. Advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain, Big Data Analytics, and Transport Management Systems (TMS) are revolutionizing how goods and information flows across borders by enhancing visibility, traceability, and coordination in supply chains (Christopher, 2016; UNCTAD, 2023). These technologies have become critical enablers of trade competitiveness, especially in developing economies where efficient logistics systems can

significantly reduce transaction costs and delays associated with cross-border trade (Gor & Muturi, 2019).

Within Africa, technology-enabled logistics systems are central to realizing the objectives of the African Continental Free Trade Area (AfCFTA). The AfCFTA framework aims to increase intra-African trade by 52% through improved transport, border, and customs management systems that rely on digital integration and automation (AfCFTA Secretariat,

2024). Digitalization of logistics under AfCFTA therefore represents not only a trade facilitation mechanism but also a strategic pathway toward industrialization, regional value chain participation, and sustainable economic growth.

For Rwanda, the adoption of technology-driven logistics aligns closely with national development agendas such as Vision 2050, the National Strategy for Transformation (NST1), and the Smart Rwanda Master Plan. These policy frameworks prioritize ICT-driven competitiveness and emphasize the role of digital technologies in enhancing productivity, export performance, and integration within global markets (MINICT, 2025). Rwanda has made commendable progress in expanding ICT infrastructure, including broadband connectivity and digital government platforms. Initiatives like the Rwanda Electronic Single Window have already reduced customs clearance times and increased transparency in trade facilitation (Nizeyimana & DeWulf, 2015).

Despite these advancements, however, the adoption of digital logistics technologies across key sectors remains limited. Many trade-supporting institutions and humanitarian organizations continue to rely on basic systems such as barcode scanners and manual record-keeping rather than fully integrated digital solutions like RFID, IoT, and cloud-based inventory platforms (Husein & Ibrahim, 2023). This slow transition constrains real-time coordination and visibility, thereby limiting Rwanda's ability to achieve seamless integration into regional and international trade networks.

Moreover, structural challenges such as high implementation costs, limited digital literacy, and inadequate infrastructure continue to impede the full-scale digitalization of logistics systems (Osunmuyiwa, Biermann, & Kalfagianni, 2017). Financial barriers, coupled with fragmented data systems and interoperability issues, reduce the efficiency of logistics networks and increase the cost of trade transactions (Wang, Chen, & Park, 2025). These obstacles highlight a persistent gap between Rwanda's digital trade ambitions and the actual operational capacity of logistics actors.

In this context, technology-driven logistics is not merely a technical enhancement but a strategic imperative for Rwanda's trade modernization. Efficient, data-driven logistics systems are crucial for improving transparency, reducing border delays, and strengthening supply-chain resilience under AfCFTA. This study therefore examines how the integration of digital logistics tools within Rwanda's trade ecosystem specifically through organizations such as the Adventist Development and Relief Agency

(ADRA) Rwanda can enhance national trade efficiency, support export competitiveness, and accelerate regional integration.

RESEARCH PROBLEM

In today's interconnected trade environment, logistics and supply-chain efficiency are key determinants of a nation's trade competitiveness. The ability to move goods quickly, accurately, and cost-effectively across borders relies increasingly on the adoption of digital technologies that enable real-time tracking, coordination, and information exchange (Christopher, 2016; UNCTAD, 2023). Yet despite global progress in logistics digitalization, many developing economies, including Rwanda, continue to face structural, financial, and institutional barriers that limit the full integration of technology-driven systems in trade operations.

Over the past decade, Rwanda has made significant policy strides toward becoming a regional leader in digital transformation. National frameworks such as Vision 2050, the National Strategy for Transformation (NST1), and the ICT and Innovation Policy (2024–2029) recognize technology as a driver of economic growth and trade facilitation (MINICT, 2025). Similarly, the African Continental Free Trade Area (AfCFTA) highlights digital infrastructure, interoperable customs systems, and logistics innovation as essential to achieving seamless intra-African trade (AfCFTA Secretariat, 2024). However, despite this favorable policy environment, the practical implementation of technology-driven logistics solutions remains limited in Rwanda's trade-supporting sectors. Most logistics operations particularly within humanitarian and development organizations still rely on basic tools such as barcode scanners and manual record systems, with minimal adoption of advanced technologies like RFID, IoT sensors, predictive analytics, and cloud-based inventory management (Husein & Ibrahim, 2023). These technologies are critical for enhancing real-time visibility, improving warehouse management, and reducing trade delays, yet their limited use constrains Rwanda's ability to integrate efficiently within regional and global supply chains.

The gap between policy intent and operational execution reflects deeper challenges related to infrastructure, financing, and organizational readiness. According to Gor and Muturi (2019), high investment and implementation costs remain among the greatest barriers to logistics digitalization in Africa. For many Rwandan institutions, particularly non-profits and small logistics firms, limited access to digital financing mechanisms hinders large-scale investment in automation and software integration.

Furthermore, internet connectivity gaps especially in rural areas reduce the reliability of real-time data exchange, which is crucial for customs clearance and cross-border coordination (Husein & Ibrahim, 2023). Equally important, there are capacity and skills limitations across the logistics workforce. Many staff members lack the digital literacy required to operate complex platforms such as cloud systems, blockchain networks, or AI-based forecasting tools (Osunmuyiwa, Biermann, & Kalfagianni, 2017). This human-capital gap not only slows technology adoption but also affects the sustainability of digital initiatives once implemented. The lack of interoperability between systems used by different logistics actors, government agencies, NGOs, and private firms further fragments Rwanda's trade ecosystem, undermining efforts toward seamless regional integration under AfCFTA (Wang, Chen, & Park, 2025).

As a result, Rwanda's logistics sector remains digitally active but technologically uneven, characterized by partial adoption of basic tools alongside low uptake of transformative technologies. The consequences are evident in the persistence of trade inefficiencies such as delays in customs clearance, high operational costs, and limited transparency across supply chains. These inefficiencies not only constrain Rwanda's export competitiveness but also slow progress toward achieving AfCFTA's objectives of efficient, technology-enabled trade corridors.

This study therefore seeks to address this critical gap by examining how the adoption of technology-driven logistics systems can enhance trade efficiency in Rwanda. It focuses on identifying the specific technologies employed, evaluating their impact on trade logistics performance, and analyzing the barriers that hinder full digital integration within the country's logistics networks. By doing so, the study contributes evidence to inform policy formulation, investment prioritization, and institutional capacity-building aimed at strengthening Rwanda's role in regional and global trade.

RESEARCH OBJECTIVES

The purpose of this paper is to examine and assess the range of digital technologies adopted within ADRA Rwanda's logistics operations and how these tools contribute to trade-related performance. Specifically, the study seeks to analyze their functions, level of utilization, and effectiveness in improving logistics efficiency, real-time visibility, and responsiveness, thereby supporting Rwanda's broader goals of digital trade competitiveness and integration under AfCFTA.

1. To identify the logistics technologies currently used in Rwanda's trade-supporting operations (ADRA Rwanda).
2. To examine the influence of technological adoption on efficiency, visibility, and responsiveness of logistics operations that underpin trade.
3. To assess key barriers limiting the adoption and scaling of advanced logistics technologies and their implications for Rwanda's trade competitiveness.

LITERATURE REVIEW

Technology-Driven Logistics and Trade Efficiency

Digital technologies are transforming global logistics and redefining the foundations of trade competitiveness. According to Christopher (2016), logistics performance comprising transportation, warehousing, and inventory management is a major determinant of a nation's trade efficiency. The integration of advanced digital systems such as Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain, and Big Data Analytics has enabled firms to achieve higher accuracy, visibility, and coordination throughout supply chains (UNCTAD, 2023). In developing economies, the adoption of technology-enabled logistics reduces costs associated with delays, manual documentation, and information asymmetry (Gor & Muturi, 2019). By automating routine processes and enhancing traceability, digital tools strengthen trade networks and increase competitiveness. Within Africa, the African Continental Free Trade Area (AfCFTA) recognizes technology-driven logistics as a strategic pillar for boosting intra-African trade. The AfCFTA Secretariat (2024) emphasizes that harmonized digital systems across customs, transport, and payment networks are essential to achieving regional integration and reducing non-tariff barriers.

For Rwanda, technology adoption in logistics aligns with national aspirations articulated in Vision 2050 and the National Strategy for Transformation (NST1). These policies highlight ICT-led development and trade facilitation as engines for inclusive growth (MINICT, 2025). Initiatives such as the Rwanda Electronic Single Window have already shortened clearance times and increased transparency in cross-border trade (Nizeyimana & DeWulf, 2015). Nevertheless, the diffusion of digital logistics innovations across all economic sectors remains uneven, and the modernization of logistics operations continues to face structural constraints.

Digitalization and Trade Facilitation

Digitalization enhances trade facilitation by improving efficiency, transparency, and coordination across borders. Dubey, Gunasekaran, and Childe (2019) note that systems like RFID, GPS-based tracking, and predictive analytics allow real-time cargo monitoring and proactive decision-making, thereby reducing delays and uncertainty in supply chains. UNCTAD (2023) stresses that e-customs and paperless trade platforms can lower transaction costs by up to 30 percent in developing economies. Across Africa, the rise of e-logistics platforms has revolutionized freight management and documentation processes, replacing slow manual systems with electronic data interchange. This shift has improved not only customs procedures but also coordination between traders, transporters, and regulators. In Rwanda, the integration of e-payments and digital customs declarations has supported a more predictable and transparent trade environment (MINICT, 2025). These reforms reflect a continental movement toward the digitalization of trade ecosystems in line with AfCFTA's digital integration agenda.

Technology Adoption and Trade Competitiveness

The adoption of logistics technologies is increasingly viewed as a strategic asset for improving trade competitiveness. Drawing from the Resource-Based View (RBV), Assensoh-Kodua (2019) argues that technological capabilities constitute rare and valuable resources that can yield sustainable competitive advantages. When firms or nations possess strong digital competencies, they can deliver goods faster, track shipments accurately, and adapt quickly to market changes which are key dimensions of competitiveness in international trade. Complementarily, the Technology–Organization–Environment (TOE) framework (Tornatzky & Fleischer, 1990) posits that technology adoption is influenced by technological readiness, internal organizational support, and the broader institutional environment. In Africa, even where supportive policies exist, organizations often face financial and technical limitations that slow adoption (Husein & Ibrahim, 2023). These constraints underscore the importance of creating enabling ecosystems that combine infrastructure, human capital, and policy incentives.

Empirical evidence shows that investment in predictive analytics and transport-management systems can significantly improve trade logistics. For instance, Gor and Muturi (2019) found that the deployment of digital monitoring tools in East Africa reduced delivery times and enhanced reliability. Similarly, Wang, Chen, and Park (2025) observe that

interoperable logistics platforms promote regional trade by allowing transparent data sharing among customs, ports, and freight operators.

Barriers to Digital Logistics Transformation

Despite these benefits, many African economies encounter persistent barriers to digital transformation. High initial investment costs and limited access to financing remain the foremost obstacles (Gor & Muturi, 2019). Infrastructure weaknesses especially unreliable internet and electricity also impede adoption (Husein & Ibrahim, 2023). In addition, organizational resistance to change and the shortage of skilled personnel hinder the effective use of digital systems (Osunmuyiwa, Biermann, & Kalfagianni, 2017). Donor-driven or project-based funding structures further limit sustainability, as technology investments often cease once external support ends. Limited system interoperability and lack of standardized digital platforms complicate coordination between logistics actors across borders (Wang et al., 2025). These challenges collectively slow the pace of trade digitalization and weaken Africa's ability to realize AfCFTA's vision of a single, technology-enabled market.

For Rwanda, progress in ICT infrastructure has been notable, yet gaps persist between urban and rural areas. Expanding broadband access and digital skills development remains critical to enabling nationwide adoption of advanced logistics technologies (MINICT, 2025). Addressing these issues requires coordinated investment in infrastructure, financing mechanisms, and workforce training to sustain trade modernization.

Theoretical Perspectives Linking Technology and Trade

The integration of RBV and TOE frameworks offers a multidimensional understanding of how technology drives trade efficiency. From the RBV perspective, digital tools such as analytics platforms, IoT networks, and TMS software represent valuable resources that can be leveraged to achieve superior logistics performance (Barney, 1991). When supported by appropriate managerial and institutional capabilities, these tools become strategic assets that enhance productivity and trade outcomes. Meanwhile, the TOE model situates these internal capabilities within an external context of policy and market forces. Tornatzky and Fleischer (1990) argue that external pressures, including competition and regulatory demands, often accelerate technology adoption. AfCFTA's emphasis on digital trade integration thus acts as a regional environmental driver compelling member state to modernize logistics systems. The interplay of internal readiness

and external incentives determines the overall trajectory of digital transformation within trade networks.

Emerging Research Gaps

While technology-driven logistics has transformed supply-chain performance in many parts of the world, empirical research connecting digital logistics adoption with trade efficiency in Africa particularly in Rwanda remains limited. Most existing studies focus on private-sector enterprises or manufacturing firms, leaving a knowledge gap regarding how non-governmental and humanitarian organizations, which form a significant part of Rwanda's logistics ecosystem, adopt and utilize technology to support trade facilitation and supply-chain operations (Gor & Muturi, 2019; Husein & Ibrahim, 2023). Furthermore, although Rwanda has made commendable progress in digital transformation through initiatives such as the Electronic Single Window and Vision 2050 ICT frameworks, the operational realities of logistics digitalization at the institutional level have not been adequately explored (MINICT, 2025; Nizeyimana & DeWulf, 2015). The gap between national policy ambition and practical implementation in logistics and trade-supporting organizations remains insufficiently documented in the literature.

RESEARCH METHODOLOGY

Research Context

This study was conducted within the Adventist Development and Relief Agency (ADRA) Rwanda, an international humanitarian and development organization operating across Rwanda since 1978. The research focused on ADRA's logistics and supply chain management (SCM) operations as a representative case of how digital logistics tools contribute to trade efficiency in the Rwandan context. Rwanda offers a unique research environment owing to its rapid expansion of digital infrastructure, strong commitment to ICT-led trade development, and its active participation in the African Continental Free Trade Area (AfCFTA) framework.

ADRA Rwanda was selected because it operates complex logistics systems involving procurement, warehousing, transport, and distribution functions that closely mirror national trade processes. The organization's gradual integration of digital tools such as barcode systems, transport management software (TMS), GPS tracking, and predictive analytics platforms makes it a relevant case for analyzing how technology adoption affects logistics efficiency and trade facilitation. The institutional context of ADRA Rwanda thus informed the research design, participant selection, and analytical approach,

ensuring that findings reflect both organizational realities and national trade dynamics.

Participants

The study targeted 118 staff members from ADRA Rwanda's logistics and SCM departments, including 108 operations and warehouse personnel and 10 logistics officers and managers directly involved in planning, procurement, and delivery processes. A census-style purposive sampling technique was adopted to ensure inclusion of all staff engaged in technology-driven logistics activities. This approach allowed the research to capture diverse perspectives and practical experiences from across the logistics value chain.

Data collection took place at the Kigali headquarters and selected district offices where ADRA manages substantial warehousing, transportation, and relief distribution activities. By covering both central and field-based operations, the study ensured a comprehensive understanding of technology use, constraints, and trade-related impacts across organizational levels.

Instruments of Data Collection

Two primary data collection instruments were used to obtain quantitative and qualitative insights:

1. **Structured Questionnaires:** Questionnaires served as the main data collection tool, designed to capture measurable data on the extent of technology use, perceived effectiveness, and barriers to digital logistics adoption. The instrument contained both closed-ended Likert scale items and open-ended questions to allow respondents to express detailed opinions on technology utilization, infrastructure, and trade efficiency outcomes.
2. **Semi-Structured Interviews:** Follow-up interviews were conducted with 10 logistics and trade operations managers to complement survey findings. These interviews provided deeper insights into managerial perspectives on digital transformation, funding challenges, and institutional readiness. The combination of both tools ensured data triangulation, thereby enhancing the credibility and interpretive depth of the findings.

Data Collection Procedures

Data collection was undertaken between March and April 2025. Prior to administration, participants were briefed on the study's objectives, and informed consent was obtained. Questionnaires were distributed physically at the Kigali office and digitally via secure online forms to remote field staff. Semi-structured interviews were conducted in person and,

where necessary, via teleconferencing to ensure broad coverage. Ethical principles were observed throughout where participation was voluntary, data were anonymized, and confidentiality was maintained. All collected information was securely stored in password-protected files accessible only to the research team.

Data Analysis Procedures

A mixed-methods approach was employed to analyze both quantitative and qualitative data:

1. **Quantitative Analysis:** Data from questionnaires were coded and analyzed using R software and Microsoft Excel. Descriptive statistics (means, standard deviations, percentages, and frequency distributions) summarized patterns of technology use and perceived impact. Multiple regression analysis tested relationships between independent variables (technology adoption indicators) and the dependent variable (trade and logistics performance).
2. **Qualitative Analysis:** Interview data were analyzed thematically to identify recurring patterns, perceptions, and challenges related to digital transformation. Qualitative insights were used to contextualize quantitative results, enabling a holistic understanding of the technological, organizational, and environmental factors influencing logistics performance in Rwanda.

Reliability and Validity

Reliability of the questionnaire was ensured through a pilot test conducted with 14 logistics staff from Akagera Motors, a commercial logistics firm operating in Rwanda. The pilot helped refine the questionnaire, improve clarity, and confirm reliability of the scales. The instrument achieved Cronbach's

Alpha values ranging from 0.78 to 0.84, indicating strong internal consistency across sections measuring technology use, perceived impact, and barriers.

Validity was ensured through multiple complementary approaches. Content validity was established through expert review by three specialists in trade logistics and ICT adoption, confirming that all questionnaire items accurately reflected the study objectives and AfCFTA trade priorities. Construct validity was enhanced by aligning the survey constructs with the theoretical frameworks underpinning the study, namely the Resource-Based View (RBV) and the Technology–Organization–Environment (TOE) model. Furthermore, triangulation was achieved by integrating findings from both questionnaires and semi-structured interviews, thereby strengthening interpretation and ensuring consistency between quantitative and qualitative perspectives.

Data Interpretation

Data interpretation focused on linking empirical results to the study objectives and relevant literature. Quantitative findings on technology use and performance impact were integrated with qualitative narratives to provide a multidimensional view of how digital logistics systems influence trade efficiency. Divergences between survey and interview results were critically examined to identify underlying institutional and infrastructural constraints. The interpretation emphasized the implications of technology adoption for policy formulation, trade competitiveness, and AfCFTA alignment. Findings were presented in relation to Rwanda's broader efforts to modernize logistics and position itself as a regional trade hub through technology-driven systems.

FINDINGS AND DISCUSSION

1. To Identify the Specific Technologies Employed in ADRA Rwanda's Logistics Systems Supporting Trade Efficiency

Table 1: Technologies Employed in ADRA Rwanda's Logistics Operations

	N	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Weighted Mean	Sd.
RFID	108	0 (0%)	0 (0%)	0 (0%)	90 (83.33%)	18 (16.67%)	1.83	0.37
Cloud-based inventory management	108	0 (0%)	0 (0%)	0 (0%)	65 (60.19)	43 (39.81%)	1.6	0.49
Automated data capture systems	108	(0%)	(0%)	(0%)	9 (8.33)	99 (91.67%)	1.08	0.28
GPS	108	0 (0%)	0 (0%)	0 (0%)	96 (88.89%)	12 (11.11%)	1.89	0.32

Barcode Scanning	108	12 (11.11%)	96 (88.89%)	0 (0%)	0 (0%)	0 (0%)	4.11	0.32
Manual inventory tracking	108		84 (77.78%)	24 (22.22)	(0%)	(0%)	3.78	0.42

(SD<0.5 or close to zero -Respondents responses crowded around the weighted mean),

(SD >0.5 or high -Respondents responses dispersed on the responses)

Ext. = Extensively, Mod. = Moderately, Min. = Minimally

Source: Field data

Findings show that basic logistics tools dominate ADRA Rwanda's trade operations, reflecting a pragmatic yet limited digital transformation. Barcode scanners (WM = 4.11) are universally used for goods tracking and customs documentation, making them the core digital instrument for cross-border verification and trade reliability. Manual inventory tracking (WM = 3.78) remains common due to low implementation costs, yet it restricts automation and slows real-time data exchange which is critical for efficient trade flows under AfCFTA. Predictive analytics (WM = 3.89) is emerging as a key enabler for trade-demand forecasting and supply stability, showing readiness for deeper data-driven decision-making.

Moderate use of TMS (WM = 2.79) and mobile technologies (WM = 2.78) supports last-mile delivery coordination and route optimization, contributing to improved trade responsiveness. However, advanced systems like RFID (WM = 1.83), GPS (WM = 1.89), and cloud platforms (WM = 1.60) are underutilized due to financial and infrastructural constraints. This pattern indicates that ADRA Rwanda's logistics digitalization is functional but not fully transformative, thereby limiting Rwanda's trade efficiency and competitiveness in regional markets.

2. To Examine the Influence of Technology Adoption on Trade and Logistics Efficiency

Table 2: Impact of Technology on Trade and Logistics Efficiency

LSCM operations	N	Strongly agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Weighted Mean	Sd.
Procurement processes	108	0 (0%)	12 (11.11%)	96 (88.89)	0 (0%)	0 (0%)	3.11	0.32
Distribution and delivery logistics	108	0 (0%)	94 (87.04%)	14 (12.96)	0 (0%)	0 (0%)	3.87	0.34
Monitoring and evaluation of supply chain performance	108	0 (0%)	96 (88.89%)	12 (11.11)	0 (0%)	0 (0%)	3.89	0.32
Capacity planning and forecasting	108	0 (0%)	80 (74.07%)	28 (25.93)	0 (0%)	0 (0%)	3.74	0.44

SD<0.5 or close to zero -Respondents responses crowded around the weighted mean),

(SD >0.5 or high -Respondents responses dispersed on the responses)

Source: Field data

Results indicate that technology adoption has substantially improved trade-related logistics efficiency across ADRA Rwanda's operations. Monitoring and evaluation (WM = 3.89) recorded the highest rating, showing that digital systems enhance trade accountability, reporting accuracy, and transparency. Distribution and delivery (WM = 3.87) also benefit strongly, with digital tools reducing shipment delays and improving reliability across Rwanda's trade corridors. Capacity planning and forecasting (WM = 3.74) demonstrate growing use of digital tools for predicting trade volumes, ensuring better alignment between supply and export demand. However, procurement processes (WM = 3.11) remain partly manual, revealing low automation in supplier coordination and contract management, which continues to hinder efficiency in trade documentation and sourcing.

Regression analysis confirmed a strong positive relationship between technology adoption and trade performance ($R = 0.961$, $R^2 = 0.924$), indicating that over 92% of logistics performance variation can be explained by technological integration. This underscores that strengthening digital adoption directly enhances Rwanda's trade reliability and responsiveness under the AfCFTA framework.

Table 3: Planning and Prediction (Forecasting) in Trade Logistics Operations

Activity	Strongly agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Weighted Mean (WM)	SD
Use of Predictive Analytics for Demand Forecasting	0 (0%)	96 (88.89%)	12 (11.11%)	0 (0%)	0 (0%)	3.89	0.32
Capacity Planning and Resource Allocation	0 (0%)	80 (74.07%)	28 (25.93%)	0 (0%)	0 (0%)	3.74	0.44
Integration of Forecasting Tools with Procurement and Distribution	0 (0%)	76 (70.37%)	32 (29.63%)	0 (0%)	0 (0%)	3.61	0.47
Use of Real-Time Data for Supply Forecast Adjustments	0 (0%)	74 (68.52%)	34 (31.48%)	0 (0%)	0 (0%)	3.58	0.46

SD<0.5 or close to zero -Respondents responses crowded around the weighted mean),

(SD >0.5 or high -Respondents responses dispersed on the responses)

Source: Field data

The results show that digital forecasting and planning tools are increasingly influencing ADRA Rwanda's logistics and trade performance, though adoption remains at a moderate stage. Predictive analytics (WM = 3.89) and monitoring systems (WM = 3.89) emerges as the most utilized forecasting method, enabling accurate demand estimation and improved trade-supply balance, particularly in export-linked programs. Capacity planning and resource allocation (WM = 3.74) also demonstrate steady application of data-driven tools that enhance warehouse optimization and delivery scheduling.

However, integration of forecasting systems with procurement and distribution (WM = 3.61) is still partial, indicating that digital forecasting operates largely as an isolated process rather than a fully synchronized element of end-to-end trade logistics. Similarly, limited real-time data utilization (WM = 3.58) reflects infrastructural and connectivity constraints that reduce responsiveness to sudden trade-demand shifts.

Overall, these findings suggest that Rwanda's logistics planning systems are evolving from manual scheduling toward predictive, data-supported decision-making. While the foundation for digital forecasting exists, full integration across procurement, warehousing, and distribution will be essential to achieve AfCFTA-aligned trade efficiency and market resilience.

3. To Assess the Barriers Limiting the Adoption and Scaling of Digital Logistics Technologies

Table 4: Financial and Organizational Barriers to Technology Adoption

	N	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Weighted Mean	Sd.
Data security concerns	108	0 (0%)	0 (0%)	20 (18.52%)	88 (81.48%)	0 (0%)	2.19	0.39
Limited internet connectivity	108	12 (11.11%)	96 (88.89%)	0 (0%)	0 (0%)	0 (0%)	4.11	0.32
Resistance to Change	108		15 (13.89%)	93 (86.11%)	0 (0%)	0 (0%)	3.14	0.35
High implementation Cost	108	96 (88.89%)	12 (11.11%)	0 (0%)	0 (0%)	0 (0%)	4.89	0.32
Lack of suitable automation	108	0 (0%)	0 (0%)	0 (0%)	101 (93.52%)	7 (6.48%)	1.94	0.25
Regulatory restrictions	108	0 (0%)	0 (0%)	0 (0%)	15 (13.89%)	93 (86.11%)	1.14	0.35
Budget constraints	108	96 (88.89%)	12 (11.11%)	0 (0%)	0 (0%)	0 (0%)	4.89	0.32

(SD<0.5 or close to zero -Respondents responses crowded around the weighted mean),

(SD >0.5 or high -Respondents responses dispersed on the responses)

Source: Field data

Findings highlight financial and infrastructural barriers as the leading obstacles to digital logistics adoption. Both high implementation costs and budget constraints achieved the highest weighted means ($WM = 4.89$), showing near-unanimous agreement among staff that funding shortages remain the greatest constraint to modernizing logistics systems. Limited internet connectivity ($WM = 4.11$) also ranked highly, confirming that unreliable infrastructure hampers real-time trade data exchange and customs coordination.

Resistance to change ($WM = 3.14$) and limited digital skills ($WM = 3.11$) reflect organizational readiness challenges, where staff adaptation and technical expertise lag behind technology availability. Integration challenges ($WM = 3.19$) indicate fragmented digital systems that restrict data interoperability between Rwanda and regional partners, weakening AfCFTA-aligned trade connectivity. Data security concerns ($WM = 2.19$) ranked lowest, suggesting that while cybersecurity awareness is limited, financial and capacity constraints currently overshadow digital safety concerns.

Overall, these barriers especially cost, infrastructure, and capacity gaps are slowing Rwanda's shift toward fully digital, transparent, and cost-effective trade logistics. Strengthening digital financing, connectivity, and workforce skills is key to achieving AfCFTA-aligned trade competitiveness.

Overall Discussion of Findings

The overall analysis reveals a clear pattern showing that digital logistics tools are gradually improving Rwanda's trade efficiency, but financial, infrastructural, and human-capacity barriers continue to limit progress. ADRA Rwanda's reliance on barcode scanners and predictive analytics demonstrates readiness for data-driven operations, yet the absence of advanced tools such as RFID, IoT, and blockchain restricts real-time traceability and transparency across regional supply chains. The regression results ($R^2 = 0.924$) confirm that technology adoption significantly explains logistics performance, proving its strategic importance for Rwanda's participation in AfCFTA trade systems. However, without stronger digital financing instruments, broadband expansion, and capacity-building initiatives, the transition toward a fully digital logistics ecosystem will remain incremental.

Overall, the study's findings emphasize that bridging Rwanda's trade efficiency gap requires not only technological upgrades but also systemic collaboration among government, NGOs, and the private sector. Through coordinated policy, investment, and innovation, Rwanda can transform digital logistics into a catalyst for AfCFTA-aligned trade growth and regional integration.

CONCLUSION

The study demonstrates that technology adoption is a powerful enabler of trade efficiency, explaining over 92% of logistics performance variation ($R^2 = 0.924$) in ADRA Rwanda's operations. Findings reveal that basic digital tools, particularly barcode scanners and predictive analytics, have significantly enhanced inventory management accuracy, demand forecasting, and delivery coordination, thereby improving Rwanda's overall trade responsiveness and transparency. However, advanced technologies such as RFID, GPS tracking, IoT, and cloud-based systems

remain underutilized due to high implementation costs, weak internet connectivity, and limited technical capacity. This under-adoption reduces real-time trade visibility and cross-border interoperability, both essential for achieving the seamless logistics integration envisioned under AfCFTA.

The results further show that while Rwanda's digital foundations are strong supported by Vision 2050, NST1, and the FinTech Strategy (2024–2029), implementation gaps persist between policy intent and operational execution. Financial and infrastructural barriers ($WM = 4.89$ and 4.11 respectively) dominate the digitalization landscape, constraining logistics modernization. Nonetheless, the widespread use of predictive analytics ($WM = 3.89$) indicates readiness for broader data-driven trade forecasting and analytics adoption.

Overall, the study concludes that Rwanda's logistics sector is digitally active but technologically uneven. To strengthen its trade competitiveness under AfCFTA, Rwanda must accelerate digital integration, foster innovation partnerships, and invest strategically in infrastructure, workforce skills, and interoperable logistics systems. Through multi-stakeholder collaboration, digital logistics can evolve into a fully integrated engine driving regional trade growth and economic transformation.

RECOMMENDATIONS

Policy and Strategic Recommendations

1. **Promote Digital Trade Financing Instruments:** The Government of Rwanda and development partners should create financing mechanisms that lower investment costs for logistics digitalization, including credit facilities and innovation funds for NGOs and SMEs engaged in trade operations.
2. **Expand National ICT Infrastructure:** Strengthening broadband and mobile network coverage, especially in remote trade corridors,

will enhance real-time tracking, customs coordination, and data exchange across borders.

3. Foster Public–Private Partnerships (PPPs): Collaboration between the public sector, private logistics firms, and international agencies can accelerate technology transfer, training, and innovation in logistics systems that support AfCFTA implementation.
4. Strengthen Capacity Building and Digital Skills Development: Continuous training for logistics personnel in digital tools such as predictive analytics, IoT systems, and blockchain will improve user confidence and maximize trade efficiency outcomes.
5. Enhance System Integration and Interoperability: The Ministry of Trade, MINICT, and Rwanda Revenue Authority should develop standardized trade data systems to ensure interoperability between NGOs, customs authorities, and regional partners for seamless trade facilitation.
6. Prioritize Affordable and Scalable Technologies: Encourage phased adoption of low-cost, high-impact tools such as mobile platforms, TMS, and predictive analytics that can be gradually expanded toward more advanced systems as capacity grows.
7. Promote Gender-Inclusive Digital Trade Participation: Address gender imbalance (77.8% male workforce) by empowering women through targeted training and mentorship in digital trade logistics roles to promote inclusive innovation.

SUGGESTIONS FOR FUTURE RESEARCH

1. Cross-Sectoral Comparative Studies: Future studies should explore technology adoption and trade efficiency across multiple Rwandan sectors such as manufacturing, agriculture, and export logistics to identify sector-specific digital transformation trends.
2. Regional Analysis under AfCFTA: Conduct comparative research among East African Community (EAC) member states to assess progress, challenges, and best practices in implementing technology-driven trade logistics under the AfCFTA framework.
3. Digital Skills and Organizational Readiness: Examine how workforce digital literacy and leadership commitment influence successful technology adoption in trade-supporting organizations.
4. Longitudinal Impact Studies: Future research could analyze how continuous upgrades of

logistics technologies affect trade integration, transaction costs, and Rwanda's export competitiveness over time.

5. Integration of Emerging Technologies: Investigate the potential role of AI, Blockchain, and IoT-based systems in enhancing trade data transparency, risk management, and supply-chain forecasting within Rwanda's logistics landscape.
6. Evaluation of Digital Policy Effectiveness: Assess the outcomes of Rwanda's digital trade policies (NST1, Vision 2050, and FinTech Strategy 2024–2029) to determine how effectively they bridge the gap between policy formulation and practical adoption.

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