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Adoption and Application of Technology in Logistics and Supply Chain Management: Evidence from ADRA Rwanda

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Abstract: Technology has become a cornerstone of efficiency, visibility, and responsiveness in modern logistics and supply chain management (LSCM). Within humanitarian operations, digital innovations are essential for overcoming logistical bottlenecks, ensuring accountability, and accelerating service delivery. This study evaluated the adoption and contribution of digital technologies in enhancing the supply-chain performance of the Adventist Development and Relief Agency (ADRA) in Rwanda. Using a purposive sampling strategy, data were collected from 108 ADRA staff and managers through structured questionnaires and key informant interviews. Quantitative data were analyzed using descriptive statistics, frequency tables, weighted means, standard deviations, and percentages while inferential analysis applied multiple regression using R software for statistical validation. Findings revealed that ADRA Rwanda relies primarily on foundational technologies such as barcode scanning (96 respondents, 88.89%) and manual inventory tracking (84 respondents, 77.78%), which are widely integrated across logistics operations. By contrast, advanced systems such as RFID (90 respondents, 83.33%), cloud-based platforms (65 respondents, 60.81%), and automated data-capture tools (99 respondents, 91.67%) remain largely underutilized. In planning and forecasting, predictive analytics (96 respondents, 88.89%) showed moderate adoption, while technologies such as Artificial Intelligence (AI), Blockchain, and the Internet of Things (IoT) exhibited minimal integration (above 87%). Despite this, digital tools were found to contribute significantly to operational outcomes particularly in monitoring and evaluation (96 respondents, 88.89%), distribution and delivery logistics (94 respondents, 87.04%), and capacity planning and forecasting (96 respondents, 88.89%). Regression analysis indicated that technological use explained 92.4% of the variance in logistics performance ($R^2 = 0.924$), underscoring the strong link between technology utilization and supply chain efficiency. The study concludes that ADRA Rwanda has achieved measurable gains through the adoption of basic yet effective technologies, though progress toward advanced digital transformation remains incremental. Broader integration of mid- and high-level solutions such as AI-driven forecasting, blockchain-based transparency, and IoT-enabled tracking will be essential to strengthen real-time visibility and data-driven decision-making. The study contributes empirical evidence to the discourse on digital transformation in humanitarian supply chains and provides actionable recommendations to guide NGOs in scaling technological adoption within resource-constrained environments.

Keywords: Logistics and supply chain management, ADRA Rwanda, technology adoption, humanitarian logistics, digital transformation, IoT, RFID, GPS, AI.

INTRODUCTION

In an era characterized by rapid digital transformation, technology has become a defining pillar of organizational competitiveness and operational efficiency. Across industries, digital innovations are reshaping how organizations plan, execute, and monitor their operations. Within logistics and supply chain management (SCM), technological tools have revolutionized processes such as procurement, warehousing, transportation, and distribution, driving improvements in accuracy, visibility, and responsiveness (Christopher, 2016). From automation and predictive analytics to mobile tracking, artificial intelligence (AI), and cloud-based platforms, these innovations have redefined operational performance in both private and humanitarian sectors (Savushkin, 2024).

Globally, effective supply chains have evolved beyond the physical movement of goods to incorporate complex digital networks where real-time data visibility, predictive analytics, and automation are key determinants of success. Digital systems such as radio-frequency identification (RFID), the Internet of Things (IoT), and big data analytics facilitate seamless communication across multiple stakeholders, enhancing transparency and reducing inefficiencies (Dubey, Gunasekaran, & Childe, 2021).

In the humanitarian context, logistics plays a central role in ensuring that relief items, food, and essential supplies reach vulnerable populations in a timely and accountable manner. Humanitarian supply chains operate in environments characterized by uncertainty, urgency, and limited infrastructure, making efficiency and visibility crucial (Altay, Kovács, & Spens, 2023). Technologies such as barcode systems, RFID, global positioning systems (GPS), IoT sensors, and predictive analytics enhance these functions by enabling real-time data sharing, improving coordination, and reducing waste (Kovács & Spens, 2023). Through such innovations, humanitarian organizations can strengthen decision-making, optimize resource allocation, and enhance responsiveness during emergencies. However, despite the proven advantages of digital transformation, adoption levels across non-governmental organizations (NGOs) in developing countries remain uneven. Many humanitarian actors continue to depend on manual or semi-automated systems for inventory tracking, procurement management, and reporting (Dubey et al., 2021).

The Adventist Development and Relief Agency (ADRA) Rwanda, established in 1978, is an affiliate of the global ADRA network, with operations spanning education, food security, health, disaster response, and economic empowerment (ESDA, 2020). Like many humanitarian organizations, ADRA operates under conditions of resource scarcity, dispersed field activities, and the constant demand for operational transparency. These realities make the integration of digital tools into its logistics and supply chain system both a necessity and a strategic opportunity. The organization's logistical operations ranging from planning and warehousing to transportation and final distribution depend heavily on the efficiency and reliability of its information flows.

Despite Rwanda's advancements in ICT infrastructure, many humanitarian organizations, including ADRA, face challenges such as limited funding, technical skills shortages, and inconsistent digital readiness. This gap between technological potential and actual implementation presents an important area of academic and practical inquiry. Examining ADRA Rwanda's technological landscape provides valuable insights into how humanitarian organizations in

developing contexts can leverage digital tools to enhance efficiency, visibility, and responsiveness.

Research Statement

Despite the recognized benefits of technology in logistics and supply chain management, the humanitarian sector continues to lag significantly behind the private sector in both adoption and integration of digital systems (Altay, Kovács, & Spens, 2023). While global corporations have leveraged automation, big data, and artificial intelligence (AI) to optimize operations, many humanitarian organizations particularly in developing countries still rely on traditional, paper-based, or semi-automated systems for procurement, inventory tracking, and reporting (Rejeb, Rejeb, & Zrelli, 2024). This technological disparity limits their ability to achieve real-time visibility, agility, and data-driven decision-making, which are critical during emergencies when rapid responses can save lives.

In Rwanda, substantial progress has been made in advancing information and communication technologies (ICT) through national initiatives which emphasizes digital transformation across all sectors of the economy (MINICT, 2025). However, these advancements have not been fully mirrored within the non-governmental sector. Many humanitarian organizations, including the Adventist Development and Relief Agency (ADRA) Rwanda, continue to depend heavily on manual or fragmented digital systems for warehousing, transportation, and distribution operations. Such limitations hinder operational visibility, delay decision-making, and constrain effective coordination between headquarters and field sites (Dubey, Gunasekaran, & Childe, 2021).

Previous studies on logistics and supply chain management in Rwanda have predominantly focused on commercial enterprises and public-sector efficiency (Gor & Muturi, 2019). Consequently, the humanitarian sector remains underexplored, particularly regarding how technology adoption affects operational performance and accountability. There is a paucity of empirical evidence detailing the types of technologies NGOs employ, their level of integration across logistics functions, and their measurable contribution to operational efficiency, visibility, and responsiveness. This gap in scholarly and practical understanding constrains both academic discourse and policy formulation aimed at improving humanitarian logistics performance in sub-Saharan Africa.

This study therefore seeks to fill that gap by conducting an in-depth examination of the technologies currently used in ADRA Rwanda's logistics and supply chain management system. Specifically, it aims to identify the range of technological tools employed, assess their level of adoption and integration across planning, warehousing, and distribution, and evaluate their contribution to overall operational efficiency.

OBJECTIVES OF THE STUDY

The primary objective of this paper is to to examine and evaluate the range of digital technologies adopted within ADRA Rwanda's logistics and supply chain management operations. Specifically, it aims to explore how these technologies are utilized across various functions, to improving operational efficiency, information visibility, and overall supply-chain responsiveness. Specifically, the study sought to:

1. To identify technologies currently used in logistics and supply chain management at ADRA Rwanda.
2. To assess the level of adoption and operational integration of digital technologies across ADRA Rwanda's planning and forecasting activities.
3. To evaluate the contribution of digital technologies to the efficiency, visibility, and responsiveness of ADRA Rwanda's supply chain operations.

LITERATURE REVIEW

Theoretical Framework

This study is grounded in four complementary theories that explain technological adoption and its influence on organizational performance through the Resource-Based View (RBV), the Technology-Organization-Environment (TOE) Framework, the Technology Acceptance Model (TAM), and the Social Construction of Technology (SCOT). Together, these frameworks provide a holistic lens for understanding how and why ADRA Rwanda adopts and applies technology within its logistics and supply chain management systems.

Resource-Based View (RBV)

The Resource-Based View (RBV) posits that organizations gain and sustain a competitive advantage by developing and leveraging resources that are valuable, rare, inimitable, and non-substitutable. Within the humanitarian context, technological capabilities represent such strategic resources. Digital tools like predictive analytics, RFID, AI, and IoT enhance efficiency, coordination, and transparency across the supply chain (Assensoh-Kodua, 2019; Gunasekaran, Subramanian, & Ngai, 2020). In humanitarian settings, such systems not only provide operational efficiency but also contribute to organizational legitimacy and donor confidence (Kovács & Spens, 2023).

Technology-Organization-Environment (TOE)

The Technology–Organization–Environment (TOE) framework provides a holistic explanation of how organizations adopt innovations through three interrelated contexts such as technological, organizational, and environmental. The technological context relates to factors such as compatibility, complexity, and relative advantage, while the organizational context focuses on leadership, readiness, and available resources. The environmental dimension reflects external influences such as donor expectations, regulations, and infrastructural conditions. (Rejeb, Rejeb, & Zrelli, 2024). Despite success with basic tools like barcode scanners, predictive analytics, and GPS, advanced technologies such as RFID and blockchain remain underutilized. Donor-driven accountability continues to motivate digital integration (Taiwo, Adebayo, & Muriithi, 2022).

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) emphasizes that individual user behavior is the primary determinant of successful technology adoption. It posits that acceptance is driven by two key perceptions that includes Perceived Usefulness (PU) which is the extent to which a person believes that using a system will enhance performance while Perceived Ease of Use (PEOU) refer to the degree to which one believes the system will be free of effort (Davis, 1989). These perceptions jointly influence the user's Attitude Toward Technology (ATT) and Intention to Use (ITU). As Caleb (2024) observes, high system complexity and insufficient training often discourage users from adopting new tools.

Social Construction of Technology (SCOT)

The Social Construction of Technology (SCOT) theory asserts that technological adoption is not purely a technical process but a socially negotiated one. The meaning and implementation of technology are shaped by the interactions of stakeholders such as management, field staff, and donors who interpret its value differently (Trevor & Bijker, 1984). SCOT therefore highlights the importance of organizational culture, leadership support, and shared understanding in sustaining technological change (Altay et al., 2023).

Technological Evolution in Logistics and Supply Chain Management

Technological innovation has historically driven major shifts in logistics and SCM. The early use of mechanized inventory systems in the 1960s evolved into computerized stock management and later into integrated Enterprise Resource Planning (ERP) systems during the 1990s (Savushkin, 2024). In the 21st century, the convergence of digital technologies such as IoT, big data, AI, and blockchain has transformed supply chains from linear structures into digitally interconnected ecosystems (Gunasekaran et al., 2020).

Modern supply chains now rely heavily on automation, data analytics, and cloud computing to enhance coordination and responsiveness. RFID and IoT sensors enable real-time tracking of goods, predictive analytics improve demand forecasting, and blockchain ensures secure data sharing among supply-chain partners (Zelbst, Green, & Sower, 2019; Fernández-Caramés & Fraga-Lamas, 2019). These technologies reduce uncertainty, minimize errors, and improve transparency attributes crucial for both commercial and humanitarian supply chains (Wamba & Queiroz, 2020).

In the humanitarian domain, logistics operations must adapt to unstable environments, emergency conditions, and limited infrastructure. As a result, technology adoption is often driven by the need for visibility, accountability, and resource optimization rather than profit (Altay et al., 2023). Tools such as GPS tracking, IoT sensors, drones, and cloud-based data systems have been increasingly deployed to improve last-mile delivery, enhance communication, and monitor aid distribution (Aditya et al., 2024; Hunt, 2022). Predictive analytics and AI are being tested to forecast demand during crises, while mobile applications facilitate field reporting and beneficiary tracking (Rejeb et al., 2024).

RESEARCH GAP

Although extensive literature underscores the transformative potential of technology in logistics and supply chain management (Christopher, 2016; Gunasekaran, Subramanian, & Ngai, 2020; Zelbst, Green, & Sower, 2019), the majority of existing research has concentrated on commercial and manufacturing sectors, where efficiency gains are often measured in financial terms. Studies from developed economies have demonstrated how automation, predictive analytics, and artificial intelligence enhance speed, reduce costs, and optimize inventory flows (Wamba & Queiroz, 2020; Fernández-Caramés & Fraga-Lamas, 2019). However, the humanitarian sector remains relatively underrepresented in this discourse. Humanitarian organizations differ from private entities because their objectives prioritize social impact over profit, and their operations take place in volatile, resource-constrained environments (Altay, Kovács, & Spens, 2023). Consequently, theories and findings derived from private-sector studies cannot be directly applied to NGOs without contextual adaptation. There remains a significant empirical void regarding how non-governmental organizations, especially in developing economies, adopt, integrate, and utilize digital technologies within their supply chains.

Within the African context, research on humanitarian logistics and technology adoption is still emerging. Although a few studies such as those by Rejeb, Rejeb, and Zrelli (2024) and Taiwo, Adebayo, and Muriithi (2022) have explored digital transformation in developing countries, they largely focus on barriers or conceptual frameworks rather than on concrete identification of technologies currently in use. Furthermore, there is limited quantitative evidence showing how technological tools contribute to performance indicators such as efficiency, visibility, and responsiveness in humanitarian supply chains. In Rwanda, existing studies on logistics (Mose, 2015; Gor & Muturi, 2019) predominantly examine commercial enterprises, such as transport firms and manufacturers, with little attention paid to the humanitarian or non-profit sectors. As a result, the unique operational realities of NGOs characterized by donor dependency, fragmented ICT infrastructure, and varying technical capacities remain insufficiently examined. This

oversight limits both academic understanding and policy formulation regarding the role of digital technologies in enhancing aid delivery.

Therefore, this study addresses these empirical and contextual gaps by systematically identifying the technologies currently employed at ADRA Rwanda, examining their level of adoption and integration for planning and forecasting, and evaluating their contribution to efficiency, visibility, and responsiveness in humanitarian supply-chain performance.

RESEARCH METHODOLOGY

Research Design

The study adopted a descriptive research design supported by both quantitative and qualitative methods. This mixed-method approach allowed for a comprehensive understanding of the technologies used in ADRA Rwanda's logistics and supply chain operations. The descriptive design was appropriate because it enabled the researcher to systematically describe the current technological tools and their impact on organizational efficiency. Quantitative data were gathered to measure the frequency and level of technology adoption, while qualitative insights helped explain contextual factors influencing utilization. The integration of these methods ensured triangulation, improving the validity and reliability of the findings.

Target Population

The target population consisted of 118 employees drawn from various departments within ADRA Rwanda, including logistics, procurement, administration, field coordination, and management. These participants were directly or indirectly involved in supply chain operations such as procurement, warehousing, transportation, and distribution.

According to ADRA Rwanda's 2024 organizational records, the logistics workforce includes operations managers, project officers, procurement officers, and warehouse supervisors, among others. Because the study sought insights into technology use, all respondents were expected to have basic familiarity with at least one digital system in the organization.

Sample Size and Sampling Procedure

The study identified 108 ADRA staff and 10 logistics and supply chain officers as an adequate sample for descriptive analysis. The study employed purposive and stratified random sampling to ensure representation from all functional level's senior management, operational staff, and field workers. Purposive sampling was used to select respondents with experience in technology use.

Data Collection Methods

The study employed a purposive sampling strategy using structured questionnaires and semi-structured interviews; questionnaires administered to logistics staff captured the extent of technology adoption across supply chain functions through Likert-scale and open-ended items, while interviews with logistics managers, project coordinators, and ICT officers provided qualitative insights into organizational factors influencing technology utilization, with all instruments pre-tested among ADRA staff to ensure clarity and reliability.

Data Analysis Procedures

Data analysis combined both descriptive and inferential statistics. The quantitative data from questionnaires were analyzed using Statistical Package for Social Sciences (SPSS) version 26.0. Descriptive statistics (mean, percentage, frequency, and standard deviation) were used to summarize findings. Weighted means were used to rank technologies based on their level of use, as shown in the thesis results. Qualitative data from interviews were analyzed thematically to identify patterns and relationships between technology adoption and operational efficiency.

Validity and Reliability

Instrument validity was ensured through expert review by supervisors and field practitioners. Reliability was tested using Cronbach's Alpha, which yielded a coefficient of 0.88, indicating high internal consistency. Pilot testing further confirmed the clarity of questions and the suitability of data collection tools.

Ethical Considerations

Ethical standards were maintained throughout the study. Respondents were informed about the purpose of the research and gave verbal consent before participation. Confidentiality was ensured by anonymizing personal identifiers, and participation was voluntary. Approval for the study was obtained from ADRA Rwanda's management and the Lincoln University College ethics committee.

RESEARCH FINDINGS AND DISCUSSION

Presentation of Findings

1. To identify technologies currently used in logistics and supply chain management at ADRA Rwanda.

Table 1.1: Level of Usage of Technologies in Ensuring Real-Time Tracking

	N	Ext. Used 5	Very Used 4	Mod. Used 3	Min. Used 2	Not Used 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

The findings from Table 4.4 indicate a significant gap in the use of advanced technologies for real-time tracking of items within ADRA Rwanda's logistics operations. Modern systems such as RFID, cloud-based inventory management, automated data capture systems, and GPS-enabled tracking devices show notably low usage among respondents. In contrast, traditional tools such as barcode scanning and manual inventory tracking remain dominant and widely used.

The results show that 83.33% of respondents reported minimal use of RFID technology, while 16.67% indicated they do not use it at all. This yields a low weighted mean of 1.83 and a standard deviation of 0.37, reflecting strong consensus on its limited application. These figures underscore that RFID, despite its potential to provide real-time item visibility, remains largely unimplemented at ADRA Rwanda.

From a practical perspective, this limited adoption is linked to cost and complexity. RFID requires specialized tags, readers, and software integration technologies that are often beyond the budgetary scope of humanitarian organizations operating in low-resource environments. Within the Technology–Organization–Environment (TOE) framework, this indicates that both organizational readiness and environmental context constrain adoption.

Similarly, cloud-based inventory management systems were found to have low adoption. A majority (60.19%) of respondents reported minimal use, while 39.81% said they do not use such systems at all. The resulting weighted mean of 1.60 and standard deviation of 0.49 confirm a shared view that these tools are rarely employed.

This limited use can be attributed to infrastructural and operational factors. Many ADRA warehouses and distribution sites are located in rural districts, where internet connectivity is unreliable or intermittent. Additionally, subscription fees for cloud platforms introduce recurring costs that are difficult to sustain under restricted donor budgets. These results imply that while cloud systems are theoretically suitable for improving visibility and coordination, technological and environmental readiness remain low.

The use of automated data capture systems is even more restricted. An overwhelming 91.67% of respondents indicated that they do not use Automated Data Capture Systems, and only 8.33% reported minimal use. This produced a very low weighted mean of 1.08 with a standard deviation of 0.28, signifying almost unanimous agreement.

Such technologies often associated with IoT sensors, handheld scanners, or mobile data terminals require both capital investment and skilled operators. In the humanitarian sector, their implementation is further limited by the temporary nature of projects, short funding cycles, and the need to prioritize service delivery over innovation. Consequently, ADRA Rwanda has not yet adopted Automated Data Capture Systems at scale, although their potential to improve data accuracy is recognized.

GPS-enabled tracking devices also demonstrate minimal adoption. 88.89% of respondents reported minimal use, while 11.11% said they do not use them at all. The computed weighted mean of 1.89 and standard deviation of 0.32 reinforce a strong consensus around the limited application of GPS in day-to-day logistics operations.

Although GPS systems can enhance visibility in transport and field delivery, their limited use reflects constraints such as network coverage, data subscription costs, and lack of centralized fleet management platforms. In many cases, GPS use occurs only during specific donor-funded initiatives that require strict monitoring of distribution routes. This selective use reflects a project-based, not system-based, approach to technology deployment.

In contrast, barcode scanning is widely and consistently used across ADRA Rwanda's logistics functions. The data show that 88.89% of respondents reported it as "very used" and 11.11% as "extensively used." This results in a high weighted mean of 4.11 and a low standard deviation of 0.32, indicating uniform agreement among respondents. Barcodes have become a core operational tool, ensuring efficient inventory identification, stock verification, and documentation accuracy. They are inexpensive, easy to maintain, and compatible with basic hardware, making them ideal for low-resource humanitarian contexts. This widespread adoption reflects technological simplicity, cost-effectiveness, and strong compatibility with ADRA's operational structure.

Within the RBV framework, barcode use represents a valuable and inimitable capability that enhances efficiency without overstretching resources.

Manual inventory tracking remains a critical part of ADRA Rwanda's supply chain management process. The results show that 77.78% of respondents use manual methods extensively, while 22.22% use them moderately. The corresponding weighted mean of 3.78 and standard deviation of 0.42 confirm its continued prominence in daily operations. Manual tracking methods, including paper-based ledgers and Excel sheets, act as redundancy systems that ensure continuity during power outages or network disruptions. While these methods limit real-time visibility, they provide a sense of operational reliability and data control, especially in remote project locations. This finding illustrates that the organization is navigating a hybrid phase of technological transition, balancing manual and digital processes to sustain operational performance.

Overall, the data reveal a dual-structure technology environment within ADRA Rwanda. Traditional tools such as barcode scanning and manual tracking dominate operations, while modern technologies such as RFID, cloud platforms, GPS, and ADC systems are rarely used. From a TOE perspective, this imbalance reflects both technological complexity and environmental constraints. Advanced systems require robust infrastructure and continuous funding, which are limited within the NGO's operating context. Organizational readiness is moderate, staff are trained and experienced in basic tools but not yet equipped for large-scale system integration. The Resource-Based View (RBV) supports this interpretation, suggesting that ADRA Rwanda's competitive advantage stems from effectively utilizing available and affordable resources that are simple technologies that deliver operational reliability without overburdening staff or finances.

Interviews with logistics staff corroborate the quantitative findings. ADRA Rwanda remains at an early stage of digital transformation, strategically piloting RFID and IoT projects but continuing to depend heavily on basic tools such as barcodes and Excel-based tracking. Managers emphasized that cost sensitivity and operational scale are the main factors limiting the adoption of advanced systems. They also reported ongoing efforts to explore digital innovations such as integrating RFID into high-value asset tracking and using IoT for monitoring environmental conditions of stored goods. Although these initiatives are in early stages, they represent a structured roadmap toward gradual technological upgrading.

The interpretation of Table 4.4 illustrates that ADRA Rwanda's technological landscape is shaped by practicality rather than innovation intensity. The organization prioritizes tools that balance affordability, simplicity, and reliability, reflecting a realistic approach to digital transformation in a humanitarian context. While modern technologies hold potential for improving visibility and efficiency, their full integration will depend on future investments in infrastructure, staff capacity, and donor-supported pilots.

Table 1. 2: Technologies Adoption in Distribution Processes

	N	Ext. Used 5	Very Used 4	Mod. Used 3	Min. Used 2	Not Used 1	Weighted Mean	Sd.
Robotics & Automation	108	0 (0%)	0 (0%)	0 (0%)	84 (77.78%)	24 (22.22%)	1.78	0.42
(TMS)	108	(0%)	1 (0.93%)	83 (76.85%)	24 (22.22%)	0 (0%)	2.79	0.43
Real-Time Tracking & GPS	108	0 (0%)	7 (6.48%)	77 (71.30 %)	24 (22.22%)	0 (0%)	2.84	0.51
Drone &	108	0	0	0	36	72	1.33	0.47

Autonomous Vehicle Deliveries		(0%)	(0%)	(0%)	(33.33%)	(66.67%)		
Mobile Technology	108	0 (0%)	0 (0%)	84 (77.78 %)	24 (22.22%)	0 (0%)	2.78	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

The findings from Table 1.1 indicate that technology adoption in distribution and delivery operations at ADRA Rwanda remains limited, with only modest application of basic digital tools. Advanced systems such as robotics, automation, drones, and autonomous vehicles exhibit minimal usage, while moderate uptake is observed in Transportation Management Systems (TMS), mobile technology, and GPS-based tracking. The consistently low standard deviations (below 0.5) show a strong consensus among respondents, suggesting a shared perception of technological realities within ADRA's distribution processes.

The results show that 77.78 % of respondents reported not using robotics or automation technologies, while 22.22 % reported minimal use, resulting in a low weighted mean of 1.78. This clearly demonstrates that robotic automation is virtually absent in ADRA Rwanda's logistics system. In humanitarian settings, automation is rarely prioritized due to high acquisition and maintenance costs, limited technical expertise, and relatively small throughput volumes. The TOE framework explains this as a result of low organizational readiness and unfavorable environmental conditions, where manual labor remains more cost-effective than mechanization. Hence, the lack of robotics adoption reflects rational prioritization rather than inefficiency.

Transportation Management Systems (TMS) tools show a moderate level of adoption, with 76.85 % of respondents indicating minimal use and 22.22 % reporting no use. Although the mean value (2.79) sits below the midpoint, it highlights emerging efforts to digitize transportation planning. This intermediate adoption corresponds to a transitional digital phase, where foundational systems are in place, but full automation and integration are pending. From a Resource-Based View (RBV), this shows the organization leveraging existing human and informational resources to enhance routing and vehicle scheduling despite limited technological infrastructure.

GPS and real-time tracking record slightly higher usage compared with other digital systems. About 71.30 % of respondents indicated minimal use, 6.48 % very used, and 22.22 % not used. The resulting weighted mean of 2.84 suggests moderate application, supported by some variability (SD = 0.51). These results imply that GPS tracking is used primarily in donor-monitored programs, where route verification and accountability are critical. The positive trend nonetheless signifies growing awareness of digital fleet monitoring, marking a step toward integrated visibility.

Drone-based deliveries exhibit the lowest level of usage in distribution processes. Two-thirds (66.67 %) of respondents reported no use, and one-third (33.33 %) reported minimal use, producing a very low mean (1.33). This minimal adoption reflects both technological and regulatory barriers. Drone logistics requires government clearance, specialized operators, and substantial investment factors often beyond NGO capacity. The limited uptake reinforces the notion that high-cost, high-skill technologies remain peripheral to NGO supply chains.

Mobile technologies demonstrate moderate usage, with 77.78 % of respondents indicating minimal use and 22.22 % reporting no use. Despite the low mean, field interviews reveal that mobile phones and SMS applications are integral to communication and last-mile coordination, especially in remote project sites. Under the TOE lens, this reflects high technological readiness but low organizational formalization of mobile-driven workflows.

Across all technologies, the Weighted Means range between 1.33 and 2.84, illustrating a narrow digital adoption curve. Respondents display strong consensus on limited automation but growing familiarity with intermediate technologies like TMS, GPS, and mobile platforms.

From a theoretical standpoint, the data reveal that ADRA Rwanda's distribution digitization is incremental and adaptive. Within the TOE framework, adoption is constrained by environmental factors such as funding, connectivity, policy and moderated by organizational priorities focused on humanitarian impact over efficiency metrics. The RBV perspective further clarifies that ADRA capitalizes on available, low-cost resources notably human coordination and basic ICT tools to sustain performance.

Managerial interviews reinforce this pattern indicating ADRA Rwanda experimenting with digital dispatch tracking and exploring partnerships for shared logistics systems, yet scale-up depends on external donor investment and policy alignment. Overall, the evidence indicates that while innovation awareness exists, technological diffusion in distribution remains at a limited but evolving stage.

2. To assess the level of adoption and operational integration of digital technologies across ADRA Rwanda's planning and forecasting activities.

Table 2: Adoption Level of technologies for Planning and forecasting in LSCM

		Ext. Used 5	**Very Used 4**	**Mod. Used 3**	**Min. Used 2**	**Not Used 1**	**Weighted Mean**	**Sd.**
Artificial Intelligence & Machine Learning	108	0 (0%)	0 (0%)	72 (66.67%)	36 (33.33%)	0 (0%)	2.67	0.47
Big Data Analytics	108	0 (0%)	0 (0%)	0 (0%)	10 (9.26%)	98 (90.74%)	1.09	0.29
Blockchain Technology	108	0 (0%)	0 (0%)	0 (0%)	12 (11.11%)	96 (88.89%)	1.11	0.32
Internet of Things (IoT)	108	0 (0%)	0 (0%)	0 (0%)	14 (12.96%)	94 (87.04%)	1.13	0.34
Predictive Analytics Software	108	0 (0%)	96 (88.89%)	12 (11.11%)	0 (0%)	0 (0%)	3.89	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)

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

Source: Field data

Findings from Table 2 reveal that the use of advanced digital planning technologies within ADRA Rwanda remains highly uneven, with a single tool like predictive analytics software showing

strong adoption, while all other advanced systems register extremely low utilization. The Weighted Means (WM) range from 1.09 to 3.89, and all Standard Deviations (SD) remain below 0.5, indicating strong agreement among respondents on how each technology is applied across the organization.

Predictive analytics software recorded the highest level of use across planning functions. A large majority of respondents (88.89 %) reported the technology as very used and 11.11 % as moderately used. This high WM (3.89) and low SD (0.32) confirm consistent and widespread adoption of this tool. Interviews with managers indicated that ADRA Rwanda employs spreadsheet-based forecasting templates and simple predictive models to estimate demand and plan procurement cycles. This reliance on accessible analytics tools demonstrates that the organization values data-driven planning but favors low-cost, user-friendly software over complex enterprise systems.

Artificial Intelligence (AI) and machine-learning applications are still at an introductory stage. Approximately two-thirds of respondents (66.67 %) described usage as minimal, and one-third (33.33 %) reported no use. The moderate WM (2.67) indicates some exploratory efforts possibly through donor-supported projects or external technical assistance, but the low SD suggests consensus that AI is not yet embedded in daily planning. From the Technology–Organization–Environment (TOE) perspective, AI adoption is constrained by the need for advanced analytical capacity, high computational requirements, and the absence of integrated datasets.

Big Data analytics registers minimal adoption, with 90.74 % of respondents stating no use and only 9.26 % reporting minimal use. The extremely low WM (1.09) and narrow SD (0.29) confirm near-unanimous agreement that this technology is largely absent. While the humanitarian sector globally is investing in data-intensive planning, ADRA Rwanda still relies on smaller, structured datasets that do not require complex analytic platforms. Financial constraints, limited technical expertise, and fragmented data sources explain this minimal utilization.

Blockchain also records very limited adoption: 88.89 % of respondents reported no use and 11.11 % minimal use. With a WM of 1.11, the technology remains conceptual rather than practical. Although blockchain could enhance transparency in procurement and donor reporting, its high infrastructure demands, and lack of contextual familiarity make it unsuitable for current humanitarian operations. The low SD (0.32) confirms organization-wide consensus on its non-implementation.

Internet of Things (IoT) applications show a similar pattern: 87.04 % of respondents reported no use and 12.96 % minimal use, producing a WM of 1.13. This demonstrates that sensor-based monitoring and automated data capture have not yet been integrated into ADRA Rwanda's planning environment. The finding aligns with earlier results (Tables 1.1 and 1.2), confirming that automation and connected-device technologies are still beyond the organization's current digital maturity level.

Overall, the data shows a selective and cautious approach to digital adoption. Predictive analytics has achieved moderate institutionalization, while AI, Big Data, Blockchain, and IoT remain largely untapped. The consistently low SD values (< 0.5) highlight shared perceptions across departments, suggesting that digital capacity gaps are systemic rather than unit specific. From a theoretical viewpoint, the results reinforce the Resource-Based View (RBV) and TOE explanations where ADRA Rwanda prioritizes technologies that fit existing resources, skills, and budgets, advancing digital transformation incrementally rather than comprehensively. The organization leverages simple predictive tools that generate tangible value while postponing investment in complex, high-cost innovations until greater financial and infrastructural readiness is achieved.

Table 3: Contribution of digital technology to the LSCM Operations

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

Findings from Table 3 indicate that the contribution of digital technologies on ADRA Rwanda's logistics and supply chain management (LSCM) operations varies across functional areas. The Weighted Means (WM) range from 3.11 to 3.89, showing that technologies currently in use such as barcode scanning, mobile communication, predictive analytics, and spreadsheet-based systems have contributed moderately to operational improvement. The Standard Deviations (SD), all below 0.5, reflect high consistency in respondents' perceptions.

A large majority of respondents (88.89%) agreed that digital tools improve monitoring and evaluation, while 11.11% were neutral. The high WM (3.89) indicates that technology enhances performance tracking and reporting accuracy, allowing management to make data-driven decisions. The low SD (0.32) shows strong consensus among staff. This confirms that digital tools are well-integrated in performance assessment, contributing directly to visibility and responsiveness within ADRA Rwanda's operations.

Nearly 87.04% of respondents agreed that technology contributions to distribution and delivery activities, while 12.96% remained neutral. The WM of 3.87 signifies a moderate-to-high positive impact, especially through the use of barcode scanning, GPS-enabled tracking, and mobile phones for delivery confirmations. These technologies have improved routing efficiency, delivery accuracy, and shipment visibility, thus enhancing responsiveness and coordination between warehouses and field operations.

About 74.07% of respondents agreed that technology aids planning and forecasting, while 25.93% were neutral. The WM (3.74) suggests that predictive analytics tools, Excel-based planning templates, and other simple forecasting applications contribute meaningfully to anticipating supply needs and optimizing resource allocation. The moderate SD (0.44) implies slightly varied experiences among staff, possibly due to differences in departmental exposure to digital tools. Nonetheless, this reflects a positive step toward more proactive and data-driven supply-chain planning.

Procurement shows the lowest perceived benefit from digital technologies. Only 11.11% of respondents agreed that technology enhances procurement, while 88.89% were neutral. The relatively lower WM (3.11) implies that procurement operations remain largely manual, with limited use of electronic tendering, digital approval workflows, or supplier management systems. The low SD (0.32) indicates that this perception is widely shared. This suggests that procurement digitization is still in its infancy and represents a key area for future digital transformation.

The results collectively indicate that technology has moderately improved ADRA Rwanda's LSCM efficiency, visibility, and responsiveness, particularly in monitoring, evaluation, and distribution processes. The generally high Weighted Means (above 3.7 for three of the four functions) and uniformly low SD values (< 0.5) confirm both positive performance contributions and strong consensus among staff.

From the Technology–Organization–Environment (TOE) perspective, these outcomes highlight that ADRA Rwanda's operational context supports the effective application of low- to mid-level technologies that align with its resources and infrastructure. Under the Resource-Based View (RBV), these technologies represent valuable organizational capabilities that enhance performance within existing constraints.

Overall, the evidence from Table 3 shows that digital technologies currently in use are contributing tangibly to operational efficiency, improved visibility, and better responsiveness even though full digital integration across all SCM functions has yet to be achieved.

CONCLUSION

This study examined the adoption and contribution of digital technologies in enhancing logistics and supply-chain management (LSCM) at ADRA Rwanda. Drawing upon empirical evidence from 108 respondents, the findings reveal that the organization is experiencing incremental digital transformation rather than comprehensive technological change. The conclusions are presented according to the study's three specific objectives.

1. To identify the specific technologies employed in logistics and supply-chain management at ADRA Rwanda

ADRA Rwanda's operations rely predominantly on traditional, low-cost technologies such as barcode scanning and manual inventory tracking (WM = 4.11 and 3.78). More advanced systems such as RFID (WM = 1.83), cloud-based inventory management (1.60), automated data-capture systems (WM = 1.08), and GPS (WM = 1.89) are rarely used. These results demonstrate that the organization prioritizes technologies that are affordable, reliable, and compatible with its infrastructure. Within the TOE framework, this reflects limited environmental and organizational readiness to adopt complex tools; under the RBV lens, barcode systems constitute a valuable yet basic operational capability supporting accountability and visibility.

2. To assess the level of adoption and integration of digital planning and forecasting technologies within ADRA Rwanda's supply-chain operations

Adoption and integration remain moderate to low. In planning and forecasting, predictive analytics software showed the highest use (WM = 3.89), while AI (WM = 2.67), Big Data (WM = 1.09), Blockchain (WM = 1.11), and IoT (WM = 1.13) recorded minimal usage. These findings portray ADRA Rwanda as being in an early digital-maturity phase, integrating practical mid-level technologies but lacking the financial and infrastructural capacity for high-end automation. Digital adoption is thus incremental, adaptive, and resource-constrained, consistent with TOE assertions that adoption depends on cost, complexity, and perceived compatibility.

3. To evaluate the contribution of digital technologies to the efficiency, visibility, and responsiveness of ADRA Rwanda's supply-chain operations

Limited digital adoption has generated positive operational outcomes. Technologies have improved performance across LSCM functions in monitoring and evaluation (WM = 3.89), distribution and delivery logistics (WM = 3.87), and capacity planning (WM = 3.74). Although procurement remains less digitized (WM = 3.11), the overall effect of technology on efficiency and responsiveness is significant. From the RBV standpoint, ADRA Rwanda is effectively leveraging its available digital resources to improve service delivery within its operational constraints.

RECOMMENDATIONS

1. Enhance Digital Infrastructure and Core Systems Integration: ADRA Rwanda should invest in strengthening its foundational logistics technologies such as barcode scanning, predictive analytics, GPS-enabled tracking, and Transportation Management Systems (TMS). Scaling these tools across all warehouses and field sites would promote data uniformity, improve real-time visibility, and reduce operational delays. This should be supported by reliable internet connectivity and adequate ICT infrastructure, particularly in rural project areas, through partnerships with donors and service providers.
2. Institutionalize Digital Capacity Building and Change Management: Continuous staff training in digital literacy, data analytics, and system utilization is essential to enhance organizational readiness and minimize resistance to technology adoption. Developing internal digital champions and embedding technology competencies into performance objectives will ensure long-term sustainability. Capacity-building efforts should also include procurement and management teams to support full digitization of workflows and accountability systems.
3. Strategically Align Digital Transformation with Organizational and Donor Priorities ADRA Rwanda should embed digital transformation within its strategic and operational plans, ensuring that technological investments align with donor expectations and national digitalization initiatives such as Rwanda's NST1 and Smart Rwanda Master Plan. Collaborative partnerships with private tech firms, government agencies, and other NGOs can facilitate pilot projects in emerging areas such as IoT, blockchain, and automation, thereby driving innovation while maintaining affordability and humanitarian relevance.

SUGGESTIONS FOR FURTHER STUDY

1. Comparative and Cross-Institutional Analyses: Future researchers should conduct comparative studies across multiple humanitarian NGOs in Rwanda and the wider East African region to assess similarities and differences in technology adoption, digital readiness, and supply-chain performance. Such studies would help identify scalable best practices and contextual barriers unique to the humanitarian sector.
2. Funding Models and Donor Influence on Digital Transformation: Further research could explore how donor funding mechanisms, reporting requirements, and project life cycles influence the adoption and sustainability of digital technologies in NGO operations. Understanding this dynamic would guide both policy and strategic decision-making for donor-recipient collaboration.
3. Longitudinal and Impact-Based Assessments: Scholars are encouraged to undertake longitudinal or quantitative impact studies to measure how incremental digital adoption affects logistics efficiency, cost reduction, and sustainability outcomes over time. These studies could also evaluate how emerging tools such as IoT, blockchain, or AI contribute to the broader goals of Rwanda's Vision 2050 and NST1 strategies.

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