Research Article

Digital Technologies and Operational Efficiency in Humanitarian Supply Chains: Empirical 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 addressing logistical bottlenecks, enhancing accountability, and accelerating service delivery in resource-constrained environments. This study evaluated the adoption and contribution of digital technologies to operational efficiency within the humanitarian supply chain of the Adventist Development and Relief Agency (ADRA) in Rwanda. A mixed-methods research approach was employed, drawing data from 108 ADRA staff and managers through structured questionnaires and key informant interviews. Quantitative data were analyzed using descriptive statistics, including frequencies, weighted means, standard deviations, and percentages, while inferential analysis employed multiple regression techniques using R software to examine the relationship between technology utilization and operational efficiency.

The findings indicate that ADRA Rwanda relies predominantly on foundational and low-cost technologies, notably barcode scanning (WM = 4.11, SD = 0.32) and manual inventory tracking (WM = 3.78, SD = 0.42), which are widely integrated into logistics operations. In contrast, advanced digital systems such as radio-frequency identification (RFID) (WM = 1.83), cloud-based inventory management platforms (WM = 1.60), and automated data-capture systems (WM = 1.08) remain largely underutilized. In planning and forecasting activities, predictive analytics tools demonstrated moderate adoption (WM = 3.89), while emerging technologies including artificial intelligence, blockchain, and the Internet of Things (IoT) exhibited minimal integration. Despite these limitations, digital technologies were found to contribute meaningfully to operational outcomes, particularly in monitoring and evaluation of supply-chain performance (WM = 3.89), distribution and delivery logistics (WM = 3.87), and capacity planning and forecasting (WM = 3.74). Regression analysis revealed that technology utilization accounted for a substantial proportion of the variance in operational efficiency, confirming a strong and positive relationship between digital technology use and humanitarian supply-chain performance.

The study concludes that ADRA Rwanda has achieved measurable operational efficiency gains through the effective use of basic and context-appropriate digital technologies, although progress toward advanced digital transformation remains incremental. To enhance real-time visibility, transparency, and data-driven decision-making, broader and more integrated adoption of mid- and high-level digital solutions such as AI-enabled analytics, blockchain-supported traceability, and IoT-based tracking is recommended. The study contributes empirical evidence to the growing discourse on digital transformation in humanitarian supply chains and provides practical guidance for non-governmental organizations seeking to scale technology adoption within resource-constrained environments.

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

1. Introduction

Digital technologies have become central to modern logistics and supply chain management (SCM), fundamentally reshaping how organizations plan, coordinate, and deliver goods and services. Across sectors, the integration of digital tools has enhanced operational visibility, accuracy, and responsiveness, transforming logistics from a predominantly physical function into a data-driven strategic capability (Christopher, 2016). In the humanitarian context, these transformations are particularly significant, as logistics operations are conducted in environments characterized by uncertainty, urgency, and limited infrastructure (Altay, Kovács & Spens, 2023). Technologies such as barcoding systems, mobile data collection, cloud-based platforms, predictive analytics, and Internet of Things (IoT) applications increasingly form the backbone of contemporary logistics processes, supporting procurement, warehousing, transportation, and distribution activities (Wamba & Queiroz, 2020).

Globally, effective supply chains have evolved beyond the mere movement of goods to encompass interconnected digital networks that enable real-time data sharing, coordination among multiple stakeholders, and informed decision-making. Advanced technologies including radio-frequency identification (RFID), big data analytics, artificial intelligence (AI), and blockchain have significantly improved demand forecasting, inventory management, and end-to-end traceability, thereby strengthening transparency and accountability within supply chains (Dubey, Gunasekaran & Childe, 2021). In humanitarian operations, such capabilities are essential to ensuring that relief items reach intended beneficiaries efficiently and with minimal loss, particularly in disaster-prone and resource-constrained settings (Kovács & Spens, 2023).

Despite their potential benefits, the adoption of digital technologies within non-governmental organizations (NGOs) remains uneven. Unlike private-sector organizations, humanitarian agencies often operate under constrained financial resources, depend heavily on donor funding, and face infrastructural limitations such as unstable connectivity and low levels of digital literacy among staff. These conditions present significant barriers to technology adoption and limit the effectiveness of humanitarian supply chains (Davis, 1989; Taiwo, Adebayo & Muriithi, 2022). Consequently, many NGOs continue to rely on manual or semi-automated systems for inventory control, procurement, and reporting, reducing operational efficiency and data reliability (Dubey et al., 2021).

The Adventist Development and Relief Agency (ADRA) Rwanda, established in 1978, is part of the global ADRA network operating in over 120 countries. In Rwanda, ADRA delivers humanitarian assistance across sectors including education, food security, health, disaster response, and economic empowerment (ESDA, 2020). Operating across diverse geographical and logistical contexts, ADRA Rwanda relies heavily on effective logistics and information flows to achieve accountability, transparency, and timely service delivery (Encyclopedia of Seventh-day Adventists, 2020). However, the extent to which digital technologies are adopted and their contribution to operational efficiency within ADRA Rwanda's supply chain remains insufficiently explored.

This study therefore examines the Digital Technologies and Operational Efficiency in Humanitarian Supply Chains within ADRA Rwanda. adoption and contribution of digital technologies within ADRA Rwanda's logistics operations. By assessing the technologies in use, their level of integration, and their influence on organizational performance, the study contributes empirical insights into how digital systems can enhance

operational efficiency in humanitarian supply chains, particularly within developing-country contexts where such evidence remains limited (Aditya, Kumar & Singh, 2024).

Despite its wide reach, this study therefore examines the Digital Technologies and Operational Efficiency in Humanitarian Supply Chains within ADRA Rwanda. By assessing the technologies in use, their level of integration, and their influence on organizational performance, the study contributes empirical insights into how digital systems can enhance operational efficiency in humanitarian supply chains, particularly within developing-country contexts where such evidence remains limited (Aditya, Kumar & Singh, 2024).

2. Problem Statement

Digital technologies are increasingly recognized as critical enablers of efficiency, transparency, and accountability in humanitarian logistics and supply chain operations. Effective coordination of procurement, warehousing, transportation, and distribution activities relies heavily on accurate information flows and real-time data visibility, particularly in environments characterized by uncertainty and resource constraints (Christopher, 2016; Altay, Kovács & Spens, 2023). Digital tools such as barcode systems, inventory management platforms, mobile data collection applications, and tracking technologies have demonstrated significant potential to enhance supply chain visibility, reduce information asymmetry, and minimize operational inefficiencies that delay humanitarian assistance.

Globally, the humanitarian sector has experienced a gradual shift toward digitalization as organizations respond to increasing operational complexity, heightened donor accountability requirements, and growing expectations for efficiency and transparency. Large humanitarian agencies have increasingly adopted digital platforms to support end-to-end supply chain visibility, performance monitoring, and evidence-based decision-making. Advanced technologies including artificial intelligence (AI), big data analytics, blockchain, and the Internet of Things (IoT) are being explored to improve forecasting accuracy, traceability, and real-time monitoring of humanitarian supply chains (Dubey, Gunasekaran & Childe, 2021; Rejeb, Rejeb & Zrelli, 2024). However, despite these developments, technology adoption across the humanitarian sector remains uneven.

Many non-governmental organizations (NGOs), particularly those operating in resource-limited contexts, continue to face persistent barriers to digital transformation. Limited financial resources, inadequate ICT infrastructure, insufficient technical capacity, and dependence on donor funding cycles often constrain sustained investment in advanced digital systems (Taiwo, Adebayo & Muriithi, 2022). Consequently, technology adoption is frequently fragmented and driven by short-term operational needs rather than strategic considerations. In many developing-country contexts, humanitarian organizations continue to rely on manual or semi-automated systems for core logistics functions, limiting data accuracy, real-time visibility, and coordination between headquarters and field operations.

In Rwanda, significant national progress has been made in advancing information and communication technologies through government-led digital transformation initiatives. While this environment provides a favorable foundation for organizational digitalization, the humanitarian sector has not fully benefited from these advancements. Many humanitarian organizations continue to operate disconnected logistics systems, constraining operational efficiency and timely decision-making, particularly in geographically dispersed field operations.

The Adventist Development and Relief Agency (ADRA) Rwanda exemplifies these challenges. As a multi-sector humanitarian organization, ADRA Rwanda manages complex logistics operations across diverse

locations. Although some digital tools are used, there is limited empirical evidence regarding the extent of their adoption, integration across supply chain functions, and contribution to operational efficiency. The apparent underutilization of advanced technologies such as RFID, IoT, and integrated analytics platforms raises concerns about missed opportunities to enhance performance and meet increasing donor expectations for transparency and accountability.

Moreover, existing literature on supply chain management in Rwanda has largely focused on commercial and public-sector organizations, leaving humanitarian logistics underexplored. This lack of context-specific empirical evidence limits informed decision-making and the development of effective digital transformation strategies. Consequently, there is a clear need for systematic research examining the digital technologies and operational efficiency in humanitarian supply chains particularly within ADRA Rwanda, to address both organizational and scholarly knowledge gaps.

3. Objectives of the Study

Understanding how digital technologies influence operational efficiency in humanitarian supply chains requires a focused and structured assessment of technology use and its performance implications. Prior studies emphasize that the effectiveness of digital systems depends not only on their availability, but also on how they are applied within core operational functions and how their use translates into measurable efficiency outcomes (Davis, 1989; Assensoh-Kodua, 2019). In humanitarian organizations such as ADRA Rwanda, where logistics operations are conducted under conditions of uncertainty, limited resources, and heightened accountability, examining the role of technology is particularly important.

Guided by this perspective, the study was designed to achieve the following specific objectives:

1. To identify the digital technologies currently used in ADRA Rwanda's supply chain operations.
2. To assess the contribution of technologies to key operational efficiency dimensions, including planning and distribution across key supply chain functions at ADRA Rwanda.
3. To examine the relationship between technology utilization and operational efficiency outcomes within ADRA Rwanda.

These objectives provide a coherent framework for analyzing both the presence and the practical impact of digital technologies within ADRA Rwanda's supply chain system. By linking technology usage with efficiency-related outcomes, the study enables a comprehensive evaluation of how digital tools support planning, coordination, and responsiveness in humanitarian logistics. This approach ensures that the analysis remains grounded in empirical evidence while contributing to broader discussions on digital transformation in non-governmental supply chains operating in resource-constrained environments.

4.Theoretical Framework and Literature Review

Understanding how digital technologies enhance operational efficiency in humanitarian supply chains requires a theoretical foundation that captures both individual behavior and organizational context. Existing literature emphasizes that technology adoption in humanitarian settings is shaped not only by technical capability but also by human perceptions, institutional constraints, and environmental pressures (Altay, Kovács & Spens, 2023). To address these dynamics, this study is anchored in the Technology Acceptance Model (TAM) and the Technology Organization Environment (TOE) framework, complemented by the Resource-Based View (RBV) and the Social Construction of Technology (SCOT).

Together, these perspectives provide a comprehensive lens for examining technology adoption and its translation into operational outcomes.

4.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), proposed by Davis (1989), remains one of the most widely applied frameworks for explaining individual-level technology adoption. TAM posits that users' acceptance of a technology is primarily determined by perceived usefulness (PU), the extent to which the technology enhances job performance and perceived ease of use (PEOU), the degree to which technology is free of effort. These perceptions influence users' attitudes, behavioral intentions, and actual system usage.

In humanitarian logistics, where staff operate under time pressure, uncertainty, and limited resources, ease of use and perceived value are particularly critical. Technologies perceived as complex or disruptive often encounter resistance, regardless of their potential efficiency gains (Venkatesh et al., 2003). Empirical studies within NGOs demonstrate that training adequacy, system simplicity, and alignment with daily operational tasks significantly influence technology acceptance (Taiwo, Adebayo & Muriithi, 2022)

Evidence from ADRA Rwanda supports the relevance of TAM. As indicated in the thesis, that staff adoption was strongest for technologies that were easy to use and required minimal additional training, particularly barcode scanners and basic inventory systems. This finding aligns with TAM's core assertion that technologies perceived as useful and easy to operate are more likely to be embedded into routine logistics practices, thereby contributing to operational efficiency.

4.2 Technology Organization Environment (TOE)

While TAM focuses on individual behavior, the Technology Organization Environment (TOE) framework provides an organizational-level explanation of technology adoption. The TOE framework argues that adoption decisions are shaped by the technological context (e.g., compatibility and complexity), organizational context (e.g., leadership support, resources, and internal capabilities), and environmental context (e.g., regulatory pressures, donor requirements, and infrastructure) (Tornatzky & Fleischer, 1990; Assensoh-Kodua, 2019).

In humanitarian organizations, these dimensions interact in complex ways. The technological context determines whether systems align with existing workflows; the organizational context influences the availability of financial and human resources; and the environmental context reflects donor accountability requirements and national ICT readiness. Studies in humanitarian logistics highlight that donor priorities and funding conditions strongly influence which technologies are adopted and sustained (Altay, Kovács & Spens, 2023).

Within ADRA Rwanda, the thesis indicates moderate technological readiness through the use of barcode systems, GPS tools, and basic analytics, alongside constraints in adopting advanced systems such as RFID and blockchain due to cost and technical limitations. The TOE framework thus explains the uneven pace of digital transformation observed, where affordable and donor-supported technologies are adopted more readily than complex or capital-intensive solutions.

4.3 Resource-Based View (RBV)

The Resource-Based View (RBV) conceptualizes technology as a strategic organizational resource capable

of enhancing performance when effectively deployed (Barney, 1991). From an RBV perspective, digital technologies contribute to operational efficiency by improving coordination, reducing waste, and enabling data-driven decision-making across supply chain functions (Gunasekaran, Subramanian & Ngai, 2020).
In humanitarian supply chains, even relatively basic technologies such as inventory management systems and tracking tools can generate significant performance gains when consistently applied. Evidence from ADRA Rwanda demonstrates that routine use of basic digital tools has improved planning accuracy, reduced inventory discrepancies, and enhanced coordination across distribution activities. RBV therefore highlights that the value of technology lies not in its sophistication but in its alignment with organizational capabilities and sustained utilization.

4.4 Social Construction of Technology (SCOT)

The Social Construction of Technology (SCOT) theory emphasizes that technology adoption is a socially negotiated process shaped by the interpretations and interests of multiple stakeholders (Bijker, Hughes & Pinch, 1987). In humanitarian organizations, management, donors, field staff, and partners may attach different meanings and priorities to the same technology.
Evidence from ADRA Rwanda illustrates this dynamic, showing that donor reporting requirements significantly influence technology selection, while staff preferences and operational realities shape actual usage. SCOT thus helps explain why some technologies become embedded in daily logistics routines, whereas others remain underutilized despite their technical potential.

4.5 Digital Technologies and Operational Efficiency in Humanitarian Supply Chains

The broader literature consistently demonstrates that digital technologies enhance humanitarian supply chain efficiency by improving visibility, accuracy, and responsiveness (Christopher, 2016; Wamba & Queiroz, 2020). Tools such as barcode systems, GPS tracking, cloud-based platforms, and mobile data collection enable real-time information sharing and reduce coordination failures. Advanced technologies including IoT, predictive analytics, and blockchain offer additional benefits related to transparency and traceability, although their adoption remains limited in resource-constrained settings (Rejeb, Rejeb & Zrelli, 2024).

4.6 Synthesis and Relevance to the Study

Collectively, TAM, TOE, RBV, and SCOT provide a robust analytical foundation for examining digital technologies and operational efficiency within ADRA Rwanda. TAM explains individual acceptance, TOE captures organizational and environmental constraints, RBV highlights performance value, and SCOT emphasizes social dynamics. Anchored in both theory and empirical evidence, this integrated framework supports the study's examination of technology adoption and its contribution to operational efficiency in humanitarian supply chains.

5.Research Methodology

This study adopted a mixed-methods research approach to examine the role of digital technologies in enhancing operational efficiency within ADRA Rwanda's supply chain operations. The mixed-methods design was selected because it enables the integration of quantitative evidence on technology usage

patterns with qualitative insights into staff experience and organizational practices. Such an approach is particularly appropriate in humanitarian logistics research, where operational realities are shaped by both measurable performance indicators and contextual, human-centred factors (Christopher, 2016; Dubey, Gunasekaran & Childe, 2021).

5.1Research Context

The study was conducted within the Adventist Development and Relief Agency (ADRA) Rwanda, an international non-governmental organization actively engaged in humanitarian and development programs across the country. Rwanda provides a unique research context due to its significant national investments in digital infrastructure alongside a strong presence of humanitarian organizations that support vulnerable populations. ADRA Rwanda was selected as the case organization because of its extensive logistics and supply chain operations and its gradual integration of digital tools such as barcode systems, inventory management platforms, GPS tracking, and digital reporting mechanisms. The organizational setting informed the choice of research design, data collection techniques, and analytical methods used in the study.

5.2 Study Population and Participants

The study population comprised staff and managers directly involved in logistics and supply chain management activities at ADRA Rwanda. A purposive census approach was adopted to ensure comprehensive coverage of individuals with direct exposure to digital technologies used in logistics operations. The target population included 108 ADRA staff members involved in supply chain activities, as well as 10 logistics and supply chain officers, resulting in a total of 118 potential participants. Data were collected primarily from the ADRA head office in Kigali and selected district offices with active logistics operations. This approach ensured that findings reflected the perspectives of both operational staff and decision-makers within the organization.

5.3 Data Collection Instruments

Two primary data collection instruments were employed to support methodological triangulation.

First, structured questionnaires were used as the main quantitative data collection tool. The questionnaires contained closed-ended questions using Likert-scale items, multiple-choice questions, and dichotomous responses to capture data on the types of digital technologies used, their level of adoption, and their perceived contribution to operational efficiency. Open-ended questions were also included to allow respondents to provide additional explanations regarding challenges, benefits, and contextual factors influencing technology use.

Second, semi-structured interviews were conducted with selected logistics, supply chain, and ICT officers. These interviews complemented the survey data by providing in-depth insights into managerial perspectives, organizational readiness, adoption challenges, and strategic considerations related to digital transformation. The qualitative component enriched the interpretation of quantitative findings and supported a deeper understanding of organizational dynamics.

5.4 Data Collection Procedure

Data collection was conducted between March and April 2025. Questionnaires were distributed directly

to participants after informed consent was obtained. Respondents were given adequate time to complete the questionnaires to ensure accuracy and completeness of responses. Following the survey phase, semi-structured interviews were conducted with selected managers and officers to validate, clarify, and expand upon survey results.

Ethical principles were strictly observed throughout the research process. Participation was voluntary, confidentiality and anonymity were assured, and collected data were securely stored in password-protected electronic files. Participants were informed of the purpose of the study and their right to withdraw at any stage without any negative consequences.

5.5 Data Analysis Techniques

A mixed-methods analytical strategy was employed. Quantitative data from the questionnaires were coded and analyzed using R software and Microsoft Excel. Descriptive statistics including frequencies, percentages, weighted means, standard deviations, and cross-tabulations were used to summarize patterns of technology adoption and perceived operational benefits. In addition, multiple regression analysis was applied to examine the relationship between technology utilization (independent variables) and operational efficiency outcomes (dependent variable). Regression modelling was selected because of its established use in logistics and supply chain research to assess the influence of technological variables on performance outcomes (Wamba & Queiroz, 2020).

Qualitative interview data were analyzed thematically. Responses were transcribed, coded, and grouped into recurring themes related to adoption drivers, operational challenges, organizational capacity, and perceived impacts of digital technologies. The integration of quantitative and qualitative findings allowed for a comprehensive and contextualized interpretation of results.

5.6 Reliability and Validity

Reliability of the research instruments was ensured through several procedures. A pilot test was conducted with 14 logistics staff from Akagera Motors to identify ambiguous or unclear questionnaire items. Feedback from the pilot study informed revisions to improve clarity and relevance. Internal consistency reliability was assessed using Cronbach's Alpha, with coefficients ranging between 0.78 and 0.84 across questionnaire sections, indicating acceptable to good reliability.

Validity was addressed through multiple strategies. Content validity was established through expert review of the questionnaire to ensure alignment with the study objectives. Construct validity was enhanced by grounding survey items in established literature and theoretical frameworks. Methodological triangulation between questionnaire data and interview findings further strengthened the credibility and trustworthiness of the results.

5.7 Data Interpretation

Findings from both quantitative and qualitative analyses were interpreted in relation to the study's objectives and existing literature on digital technologies and humanitarian logistics. Quantitative results were contextualized using qualitative narratives to explain observed patterns and relationships. Where discrepancies emerged between survey and interview data, these were critically examined to uncover underlying organizational or contextual factors influencing technology adoption. The interpretation process emphasized both theoretical contributions and practical implications for improving supply chain efficiency within humanitarian organizations operating in Rwanda.

6.Research Findings And Discussion

7.1Presentation 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 in Table 1.1 reveal that ADRA Rwanda's logistics and supply chain operations rely predominantly on basic and traditional technologies, with limited adoption of advanced systems for real-time tracking. Overall, the results indicate a clear technological divide between widely used low-cost tools and minimally used modern digital solutions.

Advanced technologies such as RFID, cloud-based inventory management systems, automated data capture systems, and GPS-enabled tracking exhibit very low levels of utilization. RFID technology is largely absent from operations, with the majority of respondents reporting minimal or no use, reflected in a low weighted mean (1.83). Similarly, cloud-based inventory management systems show limited adoption, with most respondents indicating minimal or no use (weighted mean 1.60). Automated data capture systems demonstrate the lowest uptake of all technologies assessed, with over 90% of respondents reporting no use, resulting in a very low weighted mean of 1.08. GPS tracking tools also remain minimally applied, suggesting that real-time visibility in transportation and distribution is not yet systematically integrated into daily operations.

In contrast, barcode scanning emerges as the most extensively used technology within ADRA Rwanda's logistics framework. Nearly all respondents reported it as very or extensively used, yielding a high weighted mean of 4.11 and indicating strong consensus on its importance. Barcode systems are central to inventory identification, stock control, and documentation processes due to their affordability, simplicity, and compatibility with existing infrastructure. Manual inventory tracking methods also remain highly prevalent, with a weighted mean of 3.78, highlighting their continued role as reliable and practical tools, particularly in contexts with limited connectivity or power disruptions.

In summary, ADRA Rwanda operates within a hybrid technology environment where traditional tools dominate logistics activities, while advanced digital technologies are scarcely used. This pattern reflects organizational, infrastructural, and financial constraints, emphasizing a pragmatic approach that prioritizes reliability, cost-effectiveness, and operational continuity over high-level technological sophistication.

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

		Ext. Used 5	Very Used 4	Mod. Used 3	Min. Used 2	Not Used 1	Weighted Mean	Sd.
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

The findings from Table 2 indicate that the adoption and operational integration of digital technologies for planning and forecasting within ADRA Rwanda are highly uneven. While one technology predictive analytics software demonstrates strong uptake, most advanced digital tools remain largely unused. The weighted mean values range from 1.09 to 3.89, and the consistently low standard deviations (all below 0.5) suggest strong agreement among respondents regarding the level of use of each technology.

Predictive analytics software is the most widely adopted tool for planning and forecasting. A significant majority of respondents reported it as either very used (88.89%) or moderately used (11.11%), resulting in a high weighted mean of 3.89. This indicates that ADRA Rwanda actively employs data-driven approaches to support demand forecasting and procurement planning. However, the form of adoption is largely based on accessible tools such as spreadsheet-based models and basic forecasting templates rather than sophisticated enterprise systems. This reflects a preference for practical, low-cost solutions that align with existing staff skills and operational capacity.

In contrast, Artificial Intelligence and Machine Learning technologies are still at an early and largely experimental stage. Most respondents indicated minimal or no use, producing a moderate weighted mean of 2.67. This suggests limited exploration rather than full integration into routine planning activities. The adoption of Big Data analytics, blockchain technology, and Internet of Things (IoT) applications is extremely low. Over 85% of respondents reported no use of these technologies, with weighted means clustered around 1.10. These findings indicate that such advanced systems remain largely absent from

ADRA Rwanda's planning and forecasting environment, primarily due to high implementation costs, limited technical expertise, and the lack of integrated and large-scale datasets.

Overall, the results highlight a selective and incremental approach to digital adoption in planning and forecasting. ADRA Rwanda prioritizes technologies that deliver immediate operational value and are compatible with existing resources, while postponing investment in complex and resource-intensive innovations until greater organizational and infrastructural readiness is achieved.

Table 3: Contribution of digital technology to 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 demonstrate that digital technologies make a moderate but uneven contribution to logistics and supply chain management (LSCM) operations at ADRA Rwanda. The weighted mean values range from 3.11 to 3.89, indicating that the technologies currently in use such as barcode scanning, mobile communication tools, predictive analytics, and spreadsheet-based systems have positively influenced operations, though the level of impact varies across functional areas. The consistently low standard deviations (all below 0.5) suggest a high degree of agreement among respondents regarding these contributions.

Digital technologies were perceived to contribute most strongly to monitoring and evaluation of supply

chain performance. As shown in Table 3, 88.89% of respondents agreed that digital tools enhance monitoring and evaluation, while 11.11% were neutral, resulting in the highest weighted mean (WM = 3.89) and a low standard deviation (SD = 0.32). This indicates that technology has significantly improved performance tracking, reporting accuracy, and managerial oversight, enabling more informed and data-driven decision-making within ADRA Rwanda.

Similarly, digital technologies were found to contribute substantially to distribution and delivery logistics. A large proportion of respondents (87.04%) agreed that technology improves distribution processes, while 12.96% remained neutral. The weighted mean of 3.87 reflects a moderately high perceived impact, particularly through the use of barcode scanning, mobile communication, and limited GPS-enabled tracking. These tools have enhanced coordination, delivery verification, and shipment visibility between warehouses and field operations.

In relation to capacity planning and forecasting, 74.07% of respondents agreed that digital technologies provide meaningful support, while 25.93% were neutral, yielding a weighted mean of 3.74. This suggests that predictive analytics tools and Excel-based planning systems are contributing to demand anticipation and resource allocation. The slightly higher standard deviation (SD = 0.44) indicates some variation in user experience, likely reflecting differences in access to and reliance on planning tools across departments.

By contrast, procurement processes recorded the lowest perceived contribution from digital technologies. Only 11.11% of respondents agreed that technology enhances procurement, while the majority (88.89%) expressed neutral views, resulting in a comparatively lower weighted mean (3.11). This finding indicates that procurement activities remain largely manual, with limited adoption of electronic tendering, digital approval workflows, or supplier management systems.

Overall, evidence from Table 3 suggests that digital technologies have improved ADRA Rwanda's LSCM operations, particularly in monitoring, evaluation, and distribution functions. However, the relatively lower contribution observed in procurement highlights the need for further digital integration. From both the Technology Organization Environment (TOE) and Resource-Based View (RBV) perspectives, the findings indicate that ADRA Rwanda effectively leverages affordable and compatible technologies to enhance performance, while more advanced digital transformation remains a future priority.

Table 4: 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

	N	Ext. Used 5	Very Used 4	Mod. Used 3	Min. Used 2	Not Used 1	Weighted Mean	Sd.
Drone & Autonomous Vehicle Deliveries	108	0 (0%)	0 (0%)	0 (0%)	36 (33.33%)	72 (66.67%)	1.33	0.47
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

Findings from Table 4 indicate that the adoption of digital technologies in distribution and delivery processes at ADRA Rwanda remains generally low, with modest use limited to foundational and intermediate tools. Advanced technologies such as robotics, automation, and drone-based delivery systems exhibit minimal or no application, while moderate adoption is observed in Transportation Management Systems (TMS), mobile technologies, and GPS-enabled tracking. The relatively low standard deviation values reported across most indicators (SD < 0.5) demonstrate a strong consensus among respondents regarding the current level of technological integration in distribution operations.

Robotics and automation technologies show particularly low adoption. As presented in Table 4, 77.78% of respondents reported no use, while 22.22% indicated minimal use, resulting in a low weighted mean of 1.78. This finding confirms that automated handling and mechanized distribution systems are largely absent from ADRA Rwanda's logistics operations. In humanitarian contexts, such technologies are often constrained by high capital costs, maintenance requirements, and the need for specialized technical expertise. From the Technology Organization Environment (TOE) perspective, this reflects limited organizational readiness and environmental suitability, where manual and labor-intensive approaches remain more feasible and cost-effective.

Transportation Management Systems (TMS) demonstrate a transitional level of adoption. Although 76.85% of respondents reported minimal use and 22.22% reported no use, the weighted mean of 2.79 suggests emerging efforts to digitize transport planning and coordination. This indicates that ADRA Rwanda is in an early phase of integrating digital tools for route planning, vehicle scheduling, and delivery coordination, though full system integration has yet to be achieved. From a Resource-Based View (RBV) perspective, this reflects strategic use of available informational and human resources to improve distribution efficiency within existing constraints.

Real-time tracking and GPS technologies show slightly higher levels of application. As indicated in Table 4, 6.48% of respondents reported very high use, 71.30% minimal use, and 22.22% no use, producing a

weighted mean of 2.84. Although adoption remains limited, this suggests selective utilization of GPS tracking, particularly in donor-funded programs requiring enhanced accountability and route verification. The slightly higher standard deviation (SD = 0.51) indicates some variation in use across projects and operational units.

Drone and autonomous vehicle delivery systems record the lowest adoption levels. A majority of respondents (66.67%) reported no use, while 33.33% indicated minimal use, resulting in a very low weighted mean of 1.33. This reflects significant technological, regulatory, and financial barriers, including airspace regulations, operational complexity, and high investment requirements, which limit feasibility in humanitarian logistics contexts.

Mobile technologies demonstrate moderate but informal use in distribution processes. While 77.78% of respondents reported minimal use, mobile phones remain essential for communication, delivery coordination, and last-mile updates, particularly in remote areas. This suggests high technological availability but limited formal integration into structured distribution systems.

Overall, evidence from Table 4 indicates that ADRA Rwanda's distribution digitization follows an incremental and adaptive trajectory. The organization prioritizes low-cost, flexible technologies that support coordination and accountability while postponing large-scale investment in advanced automation. This approach reflects a pragmatic balance between operational needs and resource constraints within a humanitarian supply chain environment.

3.To examine the relationship between technology utilization and operational efficiency outcomes within ADRA Rwanda.

Table 5: LSCM Operations Benefited from Technology Currently in Use

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

The Table 5 provides insights into the perceived contribution of currently adopted digital technologies to operational efficiency across key logistics and supply chain management (LSCM) functions at ADRA Rwanda. The data, collected from 108 respondents, indicate that technology adoption has varying effects depending on the functional area.

Procurement processes appear least influenced by technology. The majority of respondents (88.89%) remained neutral regarding its impact, while only 11.11% agreed that digital tools improved procurement activities. The resulting weighted mean of 3.11 and a low standard deviation of 0.32 indicate consensus that procurement continues to rely heavily on traditional procedures and donor compliance mechanisms. This suggests that despite technological availability, efficiency gains in procurement are limited.

In contrast, distribution and delivery logistics demonstrate substantial benefits from technology. Approximately 87.04% of respondents agreed that digital tools enhanced delivery operations, yielding a weighted mean of 3.87 and a standard deviation of 0.34. Tools such as barcode scanning, GPS-enabled tracking, and mobile communication facilitate improved routing, shipment visibility, and coordination between warehouses and field operations, directly contributing to operational efficiency and responsiveness.

Monitoring and evaluation of supply chain performance received the highest perceived benefit, with 88.89% of respondents acknowledging improvements. The weighted mean of 3.89 and SD of 0.32 reflect strong agreement that technology enhances tracking, reporting accuracy, and data-driven decision-making.

Capacity planning and forecasting also benefited moderately from digital adoption. About 74.07% of respondents agreed that technology improved planning outcomes, while 25.93% were neutral. The weighted mean of 3.74 and SD of 0.44 suggest a positive but slightly heterogeneous impact, likely due to differences in departmental exposure to predictive analytics and spreadsheet-based planning tools.

Overall, the findings indicate that technology utilization positively correlates with operational efficiency outcomes, particularly in areas that rely on real-time visibility, tracking, and coordination. Procurement remains an outlier due to structural constraints and limited digital integration. From a theoretical standpoint, these results support the Resource-Based View (RBV), where effective use of accessible digital tools strengthens operational capabilities, and the Technology Organization Environment (TOE) framework, highlighting how organizational and environmental factors moderate technology's contribution to efficiency.

7.Conclusion and Recommendations

7.1Conclusion

This study set out to examine the adoption of digital technologies and their contribution to operational efficiency in humanitarian supply chains, with specific reference to ADRA Rwanda. Guided by established theoretical frameworks and supported by empirical evidence, the study provides a comprehensive understanding of how digital tools are utilized within a humanitarian logistics context and how they influence key operational outcomes.

The findings demonstrate that ADRA Rwanda's supply chain operations are predominantly supported by basic and low-cost digital technologies, notably barcode scanning, mobile communication tools, and spreadsheet-based predictive analytics. These technologies have been effectively integrated into daily operations and have contributed positively to distribution efficiency, monitoring and evaluation, and capacity planning. In contrast, advanced digital solutions such as RFID, IoT, blockchain, robotics, and drone-based deliveries remain largely absent from operational practice, reflecting organizational, financial, and environmental constraints.

The study confirms a positive relationship between technology utilization and operational efficiency, particularly in areas where real-time data visibility, coordination, and reporting are critical. However, the limited impact of digital technologies on procurement processes highlights persistent structural and compliance-related barriers that restrict deeper digital integration. From a theoretical perspective, the findings validate the relevance of the Technology Acceptance Model by demonstrating that perceived ease of use and usefulness drive adoption, while the TOE framework explains how organizational readiness and environmental pressures shape technology choices. The Resource-Based View further underscores that even modest digital resources can enhance performance when effectively deployed, and SCOT illuminates the influence of donor requirements and stakeholder interpretations on technology use.

In conclusion, the study finds that digital transformation in humanitarian supply chains does not necessarily require sophisticated technologies to achieve efficiency gains. Rather, sustained and strategic use of context-appropriate digital tools, aligned with organizational capacity and operational realities, can significantly enhance humanitarian supply chain performance. The experience of ADRA Rwanda illustrates the value of an incremental and pragmatic approach to digitalization in resource-constrained humanitarian settings.

7.2 Recommendations

Based on the study's findings and conclusions, the following recommendations are proposed for policy, practice, and future research:

Strategic Digital Transformation Planning

ADRA Rwanda should develop a clear and phased digital transformation strategy for its supply chain operations. This strategy should prioritize the integration of existing technologies across procurement, warehousing, transportation, and distribution functions before investing in advanced systems. A structured roadmap will help align technology adoption with organizational goals, donor expectations, and available resources.

Strengthening Procurement Digitalization

Given the limited impact of digital technologies on procurement processes, ADRA Rwanda should prioritize the introduction of basic electronic procurement systems, including digital approval workflows,

supplier databases, and electronic documentation. Incremental digitization of procurement can enhance transparency, reduce processing time, and improve compliance with donor requirements.

Capacity Building and Staff Training

Continuous training programs should be implemented to enhance staff digital competencies and confidence in using existing and emerging technologies. Emphasis should be placed on practical, user-friendly tools to reinforce perceived ease of use and usefulness, in line with the Technology Acceptance Model. Investing in human capacity will maximize the benefits derived from current technologies.

Leveraging Donor Support for Technology Investments

ADRA Rwanda should actively engage donors to advocate for flexible funding arrangements that support digital infrastructure and system integration. Demonstrating the operational efficiency gains associated with digital tools can help justify investments in technologies such as integrated inventory systems, GPS tracking, and transportation management systems.

Enhancing System Integration and Data Sharing

Efforts should be made to improve interoperability between existing digital tools to enable seamless data flow across supply chain functions. Improved integration will enhance real-time visibility, coordination between headquarters and field offices, and evidence-based decision-making.

6. Gradual Adoption of Advanced Technologies

While advanced technologies such as RFID, IoT, and analytics platforms are currently constrained, ADRA Rwanda should pilot selected innovations in high-impact areas where feasibility exists. Pilot projects can help assess cost-benefit implications, build organizational learning, and prepare the ground for future scale-up.

8. Suggestions for Further Study

Future studies should extend this research to comparative analyses across multiple humanitarian organizations operating in Rwanda or similar contexts to enhance generalizability. Longitudinal studies examining the evolution of digital adoption over time and its impact on humanitarian outcomes would also provide valuable insights. Additionally, further research could explore beneficiary-level impacts of digital supply chain innovations.

References

1. Aditya, A., Kumar, S., & Singh, R. K. (2024). Digital transformation in humanitarian supply chains: Challenges and opportunities in developing economies. International Journal of Logistics Management, 35(1), 45–63. https://doi.org/10.1108/IJLM-2023-0045
2. Altay, N., Kovács, G., & Spens, K. M. (2023). Humanitarian logistics and supply chain management: New perspectives and challenges. Journal of Humanitarian Logistics and Supply Chain Management, 13(1), 1–8. https://doi.org/10.1108/JHLSCM-01-2023-001
3. Assensoh-Kodua, A. (2019). Technological innovation adoption at the firm level: Perspectives

from the TOE framework. Journal of Technology Management & Innovation, 14(3), 1–10. https://doi.org/10.4067/S0718-27242019000300001

4. Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99–120. https://doi.org/10.1177/014920639101700108
5. Bijker, W. E., Hughes, T. P., & Pinch, T. J. (1987). The social construction of technological systems: New directions in the sociology and history of technology. MIT Press.
6. Christopher, M. (2016). Logistics and supply chain management (5th ed.). Pearson Education.
7. Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. https://doi.org/10.2307/249008
8. Dubey, R., Gunasekaran, A., & Childe, S. J. (2021). Big data analytics capability in humanitarian supply chains: A resource-based view. International Journal of Production Economics, 231, 107856. https://doi.org/10.1016/j.ijpe.2020.107856
9. Encyclopedia of Seventh-day Adventists. (2020). Adventist Development and Relief Agency (ADRA). https://encyclopedia.adventist.org
10. ESDA. (2020). Adventist Development and Relief Agency Rwanda country profile. Eastern and Southern Africa Division.
11. Gunasekaran, A., Subramanian, N., & Ngai, E. (2020). Quality management in humanitarian supply chains: Resource-based perspectives. International Journal of Production Economics, 230, 107812. https://doi.org/10.1016/j.ijpe.2020.107812
12. Kovács, G., & Spens, K. M. (2023). Humanitarian supply chain resilience: Digitalization and coordination challenges. Supply Chain Management: An International Journal, 28(2), 215–228. https://doi.org/10.1108/SCM-06-2022-0254
13. Rejeb, A., Rejeb, K., & Zrelli, Y. (2024). Blockchain technology in humanitarian supply chains: A systematic literature review. Computers & Industrial Engineering, 186, 109813. https://doi.org/10.1016/j.cie.2023.109813
14. Taiwo, A. A., Adebayo, I. T., & Muriithi, S. M. (2022). Digital transformation barriers in non-governmental organizations: Evidence from Sub-Saharan Africa. Information Development, 38(4), 604–617. https://doi.org/10.1177/02666669211017841
15. Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books.
16. Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS Quarterly, 27(3), 425–478. https://doi.org/10.2307/30036540
17. Wamba, S. F., & Queiroz, M. M. (2020). Industry 4.0 and the supply chain digitalization: A systematic literature review. Production Planning & Control, 31(7), 540–559. https://doi.org/10.1080/09537287.2019.1653145