Leveraging technology in humanitarian supply chains: impacts on collaboration, agility and sustainable outcomes

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Abstract

Purpose – This study aims to understand the role of technology adoption (TA) in improving the efficiency and environmental sustainability (ENS) of humanitarian supply chains through collaboration and supply chain agility. This study made an attempt to explore how technological resources can be used strategically to achieve operational efficiency and contribute to sustainable humanitarian logistics.

Design/methodology/approach – The data collected from 274 respondents involved in humanitarian logistics is analyzed using the confirmatory factor analysis and the Partial Least Squares Structural Equation Modeling. These respondents include logistics managers, coordinators as well as other relevant personnel from different non-governmental organizations, international aid agencies and relief operations.

Findings – The results of this study show that TA plays a critical role in improving both collaboration and supply chain agility in humanitarian operations. It is evidenced that both collaboration and agility significantly moderate the relationship between TA and supply chain outcomes, respectively, improving the effectiveness and ENS of aid delivery. In particular, technology-facilitated collaboration and agility cut down operational costs, reduce the response time and minimize the environmental impact.

Originality/value – This study extends the application of dynamic capabilities view in humanitarian operations and supply chain and elaborates on how technological capability improves humanitarian supply chain performance. This study also highlights the mediation role of agility and collaboration to achieve aid delivery efficiency and ENS.

Keywords Technology adoption (TA), Humanitarian supply chains (HSC), Supply chain agility (SCA), Environmental sustainability (ENS), Aid delivery efficiency (ADE)

Paper type Research paper

1. Introduction

The recent years have been marked by growing challenges in the humanitarian sphere, such as addressing the aftermath of natural disasters, mitigating the consequences of conflicts or fighting pandemics (Grigoli *et al.*, 2024; Modgil *et al.*, 2022a). These situations require rapid and efficient systems of humanitarian aid delivery that that are not just prompt but also environmentally sustainable (Li *et al.*, 2019). Although the logistics has seen wide array of advancements, the use of technology in humanitarian supply chains has continued to be underdeveloped, especially considering the issue of sustainability and aid delivery efficiency (ADE).

The adoption of disruptive and emerging technologies, including artificial intelligence (Modgil *et al.*, 2022b; Mukhopadhyay *et al.*, 2024), Blockchain (Sharma *et al.*, 2024; Sharma *et al.*, 2023), drone technology (Edwards *et al.*, 2023), Big data analytics (Wamba *et al.*, 2017) and the Internet of Things (IoT) (Ehsani *et al.*, 2023), has revolutionized many industries and sectors because of the ability to improve the efficiency of operations and generate innovative approaches to complex challenges. In the commercial sector, multiple examples are illustrating how firms such as DHL use sophisticated dynamics and algorithms of logistics to reduce delivery times and increase consumer satisfaction via autonomous delivery vehicles (DHL, 2024). However, the use of such technology in the context of humanitarian supply chains (HSCs) varies significantly and remains understudied, particularly in terms of enhancing supply chain collaboration (COL) and agility (SCA), ADE and environmental sustainability (ENS).

The central issue addressed by this study is the underutilization of technological resources in HSCs, which hampers the efficiency and ENS of HSC. This study investigates how various disruptive and emerging technologies, that is, AI, blockchain, drone technology, big data analytics and the IoT, can be optimally adopted to achieve improvements in COL and agility throughout the HSC. While these technologies are perceived as having high potential for positive effects, their use in HSCs has received less

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attention, especially with regards to how they might help improve humanitarian responsiveness through the prism of ADE and ENS.

Additionally, insights can also come from industry practice. For instance, the World Food Program has implemented Blockchain technology to track the food aid from donors to needy. The technology ensures that aid reaches to the intended recipients and prevents any potential fraud (WFP, 2017). Furthermore, companies such as "Doctors Without Borders" have previously used drones to transport medical supplies to remote areas, which results in reduced delivery times and increased responses to emergency situations (DWB, 2017).

The significance of extensive technological integration within humanitarian works is evident in the statistics. In 2021, the necessity of humanitarian assistance and protection covered about 235 million people based on the report of United Nations Office for the Coordination of Humanitarian Affairs (OCHA, 2021). This number grew by approximately 40% compared to the previous year. The stats clearly indicate the need of more efficient humanitarian works. Additionally, according to the study by Logistics Cluster (2018), supply chain accounts for 73% of total emergency response expenditure. Thus, better supply chain integration may facilitate substantial cost savings and efficiency improvements (Singh, 2024a, 2024b).

While the role of technology with respect to commercial supply chains has been extensively studied in prior research (Bag *et al.*, 2023; Edwards *et al.*, 2023; Wamba *et al.*, 2017; Singh and Joshi, 2024; Iqbal and Ahmad, 2022), the relevant literature is lacking in the context of HSCs. First, there are few studies quantifying the direct effect of technology on HSC performance. Moreover, the role of COL and SCA has been understudied in humanitarian literature and how these variables mediate the relationship between technology adoption (TA) and supply chain outcomes. Finally, the environmental channel of influence has received little attention. Less attention is given to the environmental dimension of humanitarian logistics. Existing literature only measured efficiency and underrated the sustainable methods that can ensure no damage is done to the environment without affecting the delivery process (Srivastav and Bag, 2023; Modgil *et al.*, 2022a). The use of technology in humanitarian operations has also been acknowledged as a powerful agent of change, which may transform the deployment of aid in case of a disaster (Santarelli *et al.*, 2015). This transformation depends on how technological tools in use contribute to the operational aspects, such as the ADE and ensuring the ENS. The efficiency, in turn, will enable the urgent and feasible resolution of the problem without exerting pressure on future resources (Santarelli *et al.*, 2015). The discussion above leads to the formation of our research questions mentioned below:

RQ1. Does technology adoption improve aid delivery efficiency and environmental sustainability in humanitarian operations?

RQ2. Do supply chain collaboration and supply chain agility mediate the relationship between technology adoption, aid delivery efficiency and environmental sustainability?

The objective of this study is to bridge these gaps and explore the relationships between the introduction of modern technologies in a HSC, ADE and ENS, with a focus on the mediating roles of COL and agility. To summarize, the problem consists of two major parts: the importance of ensuring that humanitarian operations are effective and speedy and environmentally friendly. We used confirmatory factor analysis to validate the theoretical framework. Through this approach, it was possible to establish the reliability and compatibility of the proposed framework. Thereafter, Partial Least Squares Structural Equation Modeling (PLS-SEM) was used in detail to examine the postulated hypotheses.

The following sections of this paper are structured as follows: Literature review forms Section 2 of this study. The third section outlines the theoretical framework and states the proposed hypotheses. The research approach is explained in Section 4 above. Section 5 comprises the empirical study with a focus on data analysis. Results are discussed in Section 6, detailing how they are relevant academically and practically. Finally, Section 7 concludes the study.

2. Related research

2.1 Technology adoption in humanitarian supply chain

Over the years, the adoption of various technologies in humanitarian contexts has attracted considerable interest associated with the potential for increased efficiency and effectiveness of aid delivery (Chari and Novukela, 2023). Leading technologies include AI, blockchain, BDA and drones, which offer unique contributions to logistics operations (Wamba *et al.*, 2017; Edwards *et al.*, 2023). For example, studies conducted by Rodríguez-Espíndola *et al.* (2020) demonstrated that the integration of technologies like AI, Blockchain and 3D printing enables is essential for improving operational aspects of HSC such as information sharing, products flow and financial resources. Baharmand *et al.* (2021) also investigated how blockchain technology could ensure transparency and trust in the HSC to increase accountability and eliminate fraud. Edwards *et al.* (2023) stated that drones cut down delivery times significantly in hard-to-reach areas, which can be instrumental in quickly identifying needs following a disaster. Additionally, Ehsani *et al.* (2023) suggest that IoT-based systems enable aid and health-related organizations to monitor people remotely, suspect detection, surveillance and transportation of relief items. However, the abovementioned studies are based on the projected potential of individual technologies, and existing knowledge lacks empirical evidence explaining the practical implementation of these technologies in humanitarian environments.

2.2 Collaboration in humanitarian supply chain

Humanitarian collaboration includes involvement of various stakeholders such as non-governmental organizations (NGOs), government authorities and local people (Moshtari, 2016). Effective collaboration results in an integrated response that saves time and resources during emergencies (Grange *et al.*, 2020). Dubey *et al.* (2021) and Najjar *et al.* (2019) point out that information sharing between organizations and a join planning process lead to improved humanitarian mission outcomes. Kabra *et al.* (2015) dive deeper into the inter-organizational aspect of disaster response and identified factors that either enable or prevent integrated collaboration. Overall, the integration of stakeholders in humanitarian efforts is important, and there is scarce scholarly work on integrated ways of measuring and improving it because of the competitive nature of the work.

2.3 Supply chain agility

Agility in HSC concerns the ability to swiftly change tactics and operations according to the current need. Dubey *et al.* (2021) stated that agility in HSCs could reduce the response time significantly and provide flexibility to adjust the operations structure with a short notice. Further, Dubey *et al.* (2022) argued for new agile practices that can be scaled up to meet disaster-driven demands without excessive pre-positioning of resources. L'Hermitte *et al.* (2016) stressed upon the need of agility in humanitarian operations support the continuity of humanitarian deliveries. Thus, there is a need for more advanced framework on applying agility in conjunction with other aspects of operational and strategic humanitarian logistics, such as cost and long-term sustainability.

2.4 Aid delivery efficiency

HSC efficiency is typically measured in terms of the cost, time and accuracy of aid delivery. Increases in efficiencies ensure that maximum available resources reach the ground quickly. For example, Altay and Green III (2006) found that efficiency is mostly influenced by levels of planning and more localized information available to the logistics team. Beamon and Balcik (2008) combined delivery speed, delivery cost and order fulfillment to create measures of efficiency. However, most studies adequately contextualize the interactions among different efficiency metrics and settle for treating them as isolated phenomena rather than elements of an integrated, interacting network.

2.5 Environmental sustainability

Regarding humanitarian operations, ENS refers to minimizing the ecological footprint of logistic activities by focusing on waste, emissions and resource use reduction (Li *et al.*, 2019). Agyabeng-Mensah *et al.* (2021) concluded that green logistics practices influence in humanitarian operations and found significant benefits from using sustainable materials and energy-efficient transport modes. Similarly, Bag *et al.* (2020) stressed upon the strategic planning of operational activities for green HSC management. Further authors stressed upon building strategic partnerships with suppliers for developing capabilities for optimized resource usage. Additionally, Saari (2023) researched adoption of renewable energies in emergency medical supply chains and discussed the potential impact of reducing carbon footprints. Sustainability is often seen as a secondary concern in urgent humanitarian settings. Further investigation is required to develop environmental issues into fundamental strategic planning decisions of humanitarian logistics. Table 1 presents the key studies on similar topics.

This literature review highlights major developments and existing knowledge gaps in the key constructs associated with HSC. Although there is extensive theoretical and limited empirical evidence about the advantages of using technology, collaboration, agility, efficiency and sustainability, there has been little exploration of these factors' unification into a cohesive operating model. There is a need for future studies to build and investigate models tailored to these combinations, especially in challenging humanitarian contexts.

2.6 Dynamic capabilities view (DCV)

DCV explains dynamic capabilities as the firm's ability to integrate, build and reconfigure internal and external competences in response to changing environments (Teece *et al.*, 1997). In the field of HSC, rapid changes and a high level of volatility are present; therefore, capabilities like agility, adaptation and collaboration become crucial. DCV helps to understand the role of technology in enhancing efficiency and combatting disasters through capacity-building and improved abilities to respond to the humanitarian crisis. The application of this perspective is justified by the evidence that the TA contributes to the development of dynamic capabilities because of enhanced interaction between stakeholders and SCA, two critical factors contributing to the effectiveness of HSCs. Indeed, DCV application has established a link between technology and the usefulness of rapid dynamic capabilities in highly volatile and unpredictable environments (Eisenhardt and Martin, 2000).

3. Hypothesis formulation and theoretical model development

3.1 Technology adoption and supply chain collaboration

According to DCV, an organization's competitive advantage is derived from its ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments (Teece *et al.*, 1997). We argue that digital technologies are critical enablers of these dynamic capabilities in HSC. TA enables capabilities such as data-sharing, real-time communication and joint decision-making, which are needed for effective collaboration among diverse stakeholders in HSC (Wamba *et al.*, 2017). For example, blockchain and AI-enabled capabilities such as transparency, data accuracy and predictive decisions, which develop trust and collaboration readiness (Modgil *et al.*, 2022b) that are important for HSC collaboration. Hence, we propose:

H1. Technology adoption positively influences supply chain collaboration in humanitarian supply chain.

3.2 Technology adoption and supply chain agility

According to DCV, firms gain a competitive advantage through their ability to build competencies (Teece *et al.*, 1997). For instance, in humanitarian logistics, technological capabilities such as Blockchain and AI are essential for enhancing SCA (Rodríguez-Espíndola *et al.*, 2020; Baharmand *et al.*, 2021). By allowing for quick data processing and better situational awareness, these technologies help react to the changing crisis environment and demands quickly. Therefore,

H2. Technology adoption positively influences supply chain agility.

Table 1 Key studies on technology in humanitarian supply chain

Serial number	Author (year)	Objectives	Findings
1	Rodríguez-Espíndola *et al.* (2020)	To develop a framework that integrates latest technologies (Blockchain, AI and 3D printing) to address potential challenges in HSC	Technological integration (Blockchain, AI and 3D printing) is essential for maximum benefits in HSC. It increases transparency, traceability, accountability and allows victims to be involved in meeting their own needs
2	Dubey *et al.* (2020)	To understand the role of blockchain technology in improving transparency and trust among stakeholders in HSC	Blockchain technology enables trust among stakeholders and improve the collaboration within HSC
3	Comes *et al.* (2018)	To understand how technology can support and facilitate the planning and implementation decisions in humanitarian cold chains	The authors conclude that the challenge is to better align technology for capacity, information and decisions as well as pointing out its necessary direction of targeting the areas of uncertainty, information or irreversibility with more research
4	Dubey *et al.* (2021)	To examine the relationship between information alignment, collaboration and agility under the moderation effect of AI-enabled big data analytics capability	The results indicate that agility of HSC is enhanced by enhancing collaborative relationship. AI-enabled big data analytics provides support in enhancing collaboration among stakeholders
5	Baharmand *et al.* (2021)	To identify the drivers and barriers of blockchain application with respect to HSC and to investigate role of blockchain in enhancing transparency	Authors found out drivers of blockchain applications that majorly includes accountability, visibility collaboration and efficiency. Further researcher confirmed that blockchain positively contributes in improving visibility and traceability of HSC
6	Altay *et al.* (2018)	To examine the role of agility and resilience on HSC performance	Authors confirmed that agility and resilience as dynamic capabilities significantly influence pre disaster performance

Source: Authors

3.3 Supply chain collaboration, aid delivery efficiency and environmental sustainability

Theory of Collaborative Advantage suggests that when organizations collaborate, they often attain outcomes that are substantially beyond the reach of any single organization alone (Vangen and Huxham, 2010). In the context of HSC, effective collaboration results in pooling of resources, knowledge and organizational capabilities which translates to operational effectiveness and overall practice sustainability (Moshtari, 2016). In the case of collaborative use of efforts in logistics planning, firms are able to eliminate duplication of efforts, reduce wastage, achieve faster and more effective aid delivery and reduce adverse environmental impact achieved through joint loading transport and consignment. Thus:

H3a. Supply chain collaboration positively affects aid delivery efficiency.

H3b. Supply chain collaboration positively affects environmental sustainability.

3.4 Supply chain agility, aid delivery efficiency and environmental sustainability

Agility, as dynamic capability, ensures that organizations can respond quickly and efficiently to changing conditions and needs (Teece *et al.*, 2016), achieving maximum operational efficiency and environmental performance (Altay *et al.*, 2018). According to the DCV, the potential capacity of an organization to quickly reconfigure its resource for appropriate response and adaptation to external environmental changes is crucial in maintaining sustaining competitive advantage (Teece *et al.*, 1997). In the context of humanitarian operations, agility refers to the system of aid distribution, which can quickly adjust itself as per the changing requirement at the time of crisis. Agility is demonstrated as the ability of supply chains to re-route supplies or change the order of delivery at short notice (Singh and Acharya, 2013, 2014), when roads are blocked or priorities change. As a result, fewer delays are recorded between the shipment and delivery of the aid. SCA allows the system to change the size and the type of delivery (Singh *et al.*, 2019), which leads to minimal emissions and waste. For example, agile operations can timeously shift to use local suppliers, ensuring timely access for goods and reducing the need for long-haul transportation and, thus, decreasing carbon emissions. Hence,

H4a. Supply chain agility positively affects the aid delivery efficiency.

H4b. Supply chain agility positively affects the environmental sustainability.

3.5 Mediating role of technology adoption

Following the DCV framework, technology enriches the organizational capabilities, that is, collaboration and agility (Eisenhardt and Martin, 2000). Through tech-enabled knowledge-sharing platform, stakeholders can quickly and easily access all the information they need for a coordinated response (Wamba *et al.*, 2017). Moreover, AI and predictive analytics enhance SCA through better decisions and analysis. Here, we argue that, with the smooth flow of technology adoption, collaboration between supply chain partners improves that lead to better resource allocation and quicker response. The mediation model suggests that while TA directly impacts COL and SCA, its effect on ADE is channeled through these capabilities. Thus,

H5a. The impact of technology adoption on the aid delivery efficiency is mediated by supply chain collaboration.

H5b. The impact of technology adoption on the aid delivery efficiency is mediated by supply chain agility.

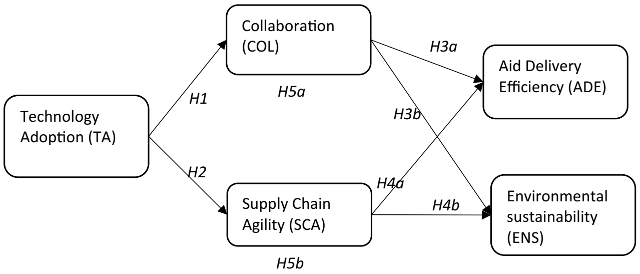
The use of technological tools would improve ENS by facilitating resource management and reducing the environmental impact of the supply chain operations (Edwards *et al.*, 2023). For example, the use of GPS and IoT to facilitate the most efficient routes for transport vehicles, which would also reduce fuel consumption and the release of harmful emissions. Moreover, collaborative platforms would help the organization share some major resources, such as transportation and storage facilities, which would have a lesser environmental impact combined (Najjar *et al.*, 2019). We argue that, as with efficiency, the pathway from TA to ENS is mediated by enhanced COL and SCA, underscoring the role of these capabilities in achieving sustainable operations. Therefore,

H6a. Supply chain collaboration mediates the impact of technology adoption on environmental sustainability.

H6b. Supply chain agility mediates the impact of technology adoption on environmental sustainability.

The discussion on *H1–H6* led to the formation of our conceptual framework as shown in Figure 1.

Figure 1 Conceptual framework



Source: Authors

4. Research design

4.1 Questionnaire and measures

The survey used in the study includes 23 items within five distinct categories: TA, COL, SCA, ADE and ENS, all grounded in previous research (Appendix Table A1). The constructs' scales were retrieved from the literature and slightly modified to address the purpose of the current study. TA has four items, inspired by the studies of Edwards *et al.* (2023) and Wamba *et al.* (2017). These items were related to technology-enabled decision-making, forecasting, deliveries, real-time tracking, logistics and operational planning. Five modified measures from the studies by Moshtari (2016) were used for the COL evaluation. These questions revolved around the information sharing frequency, joint decision-making, resource sharing, collaborative planning frequency and integration of efforts. SCA was measured with five items influenced by Dubey *et al.* (2020) and Altay *et al.* (2018) covering respond speed to demand change, operation's scalability, recovery speed from disruption and capability to handle sudden changes. The assessment of ADE was guided by four items, which were modified from Santarelli *et al.* (2015) and Kovács and Spens (2007). These included delivery lead time, delivery accuracy, volume of aid delivery and cost per delivery. ENS assessment used five adjusted items from Singh and Modgil (2024), Singh (2024a, 2024b) and Singh *et al.* (2024), focusing on waste management, carbon footprint, energy efficiency, water use and sustainable sourcing. All the scales applied a five-point Likert scale, spanning from "strongly disagree" to "strongly agree," with "neutral" as the central point. The operationalization of construct table is provided in Appendix (Table A1).

Following this, the research instrument underwent a rigorous pilot testing phase involving 21 respondents. During this phase, the validity and reliability of the questionnaire were thoroughly examined, and the results were found to be satisfactory. The pilot testing process contributes to the robustness of the research instrument, ensuring that it effectively captures the intended constructs and measures them reliably. This combination of drawing from past literature and conducting pilot testing enhances the credibility of the questionnaire and underscores the methodological rigor used in its development.

4.2 Data collection

The data was collected for this study through a comprehensive survey administered to professionals and stakeholders in the port sector. In all, 289 individuals agreed to participate, representing varied categories as disaster relief organizations, NGOs, ICT companies, government agencies, logistics and transportation firms and pharmaceutical companies. The areas covered by the study included TA, COL, SCA, ADE and ENS. The questionnaire included Likert scale questions to ascertain agreement regarding TA, ADE, sustainable activity and perceived outcomes. The respondent selection process was conducted through professional networking websites, NGO networks and other relevant social media to target a wider and more closely representative sample of the overall humanitarian operations community.

The questionnaire was distributed online to reach 850 potential respondents in the port and shipping sector. A total of 307 respondents returned the completed questionnaire. On closer inspection, 18 surveys were eliminated because they were partially filled out, and therefore, the remaining questionnaires comprised 279 respondents. This adequately tests the intended hypothesis (Hair *et al.*, 2006). Additionally, the recent supply chain study, for example, Singh *et al.* (2024), argues that as few as 150 responses are sufficient for the analysis. For demographic details of the respondents, see the appendix section (Table A2).

5. Data analysis

The research was initiated by determining the suitable sample size and the reliability of the survey instrument. Following this pre-analysis, the research was explored thoroughly by applying PLS methodology. This particular approach was chosen for the method's efficacy in assessing relationships of the causal-predictive relationships within the framework, as recommended by Hair *et al.* (2019). PLS-SEM is well suited for exploratory research and theory development and makes it relevant to analyze the association between TA and HSC performance. This approach enables to capture the measurement model and the structural model simultaneously. In this study, the applicability of PLS-SEM is justified because of its flexibility of modeling formative and reflective constructs, as well as its robustness in handling multicollinearity SEM is a method that unites factor and multiple regression analysis into one comprehensive system. Such an integration allows for a comprehensive examination of how the variables function together, broadening the understanding of their relationships. The PLS was preferred because of the potential to handle complex models with many observable and latent variables.

5.1 Common method bias (CMB)

We implemented procedural and statistical strategies for CMB to attenuate and test CMB, adopting the approach recommended by Podsakoff *et al.* (2003). The foundation of our study comprises TA, COL, SCA, ADE and ENS. We used procedural measures composed of measurement scales supported by the existing literature. Initially, the measurement scales were tested among three lecturers, an additional three doctoral students and two industry experts specialized in information system, HSC, sustainability and environmental management. The survey design included a layout to ensure clear and straightforward instructions and precision for all questions per the research purpose. Moreover, to reduce potential biases, none of the participants could access their responses post-submission, which may lead to post-submission data distortion that can otherwise be linked to social desirability.

Furthermore, we used Harman's one-factor test and the collinearity variance inflation factor (VIF) test as additional CMB management and evaluation tests. Harman's single-factor test did not detect a single factor explaining more than 50% of the variance, which means that CMB presents low risk. In addition, we conducted the VIF analysis using SmartPLS to identify potential multicollinearity between constructs. Almost all VIF scores scored way lower than the proposed threshold value of 3.3 by Hair *et al.* (2013), which proves the lack of multicollinearity and common method bias in our study.

5.2 Assessment of measurement model

Kaiser–Meyer–Olkin value of 0.752 indicates that the sample is acceptable for factor analysis. The exploratory factor analysis identified six unique factors whose eigenvalues exceeded 1, accounting for 60.453% of the total variance observed. This finding validates the convergent and discriminant validity of the study, consistent with the criterion suggested by Fornell and Larcker (1981). The measurement model evaluation involved verifying internal consistency, indicator reliability and convergent validity using the procedures proposed by Hair *et al.* (2019). As seen in Table 2, the composite reliability scores for all the factors surpassed the 0.7 cut-off mark, indicating robust internal consistency as advocated by Hair *et al.* (2019).

As shown in Table 2, the standardized factor loading, AVE and CR scores complied with the predefined benchmarks. The factor loadings varied between 0.649 and 0.897, highlighting significant associations between items and their respective factors. The minimum values observed for Cronbach's alpha (CA), CR and AVE were 0.902, 0.910 and 0.720, respectively, all exceeding the thresholds recommended by Hair *et al.* (2019), which are >0.7 for CA and CR and >0.5 for AVE. It, thus, indicates the existence of the model's convergent validity, showing that the constructs included in the model are well captured by the model's indicators, hence further validating all construct convergent validity.

Henseler *et al.* (2015) recommendations were used in assessing discriminant validity using the HTMT ratio of

Table 2 Convergent validity

Item	Loading	Outer VIF	Cronbach's alpha	CR	AVE
TA 1	0.873	2.299	0.852	0.898	0.688
TA 2	0.843	2.376			
TA 3	0.741	1.811			
TA 4	0.850	2.056			
COL 1	0.804	2.346	0.859	0.878	0.642
COL 2	0.864	2.348			
COL 3	0.887	1.981			
COL 4	0.755	1.588			
COL 5	0.678	1.509			
SCA 1	0.763	1.982	0.902	0.910	0.720
SCA 2	0.859	2.532			
SCA 3	0.887	2.081			
SCA 4	0.859	1.995			
SCA 5	0.869	1.810			
ADE 1	0.897	1.987	0.859	0.882	0.708
ADE 2	0.881	1.906			
ADE 3	0.889	2.532			
ADE 4	0.680	1.359			
ENS 1	0.649	1.227	0.842	0.857	0.626
ENS 2	0.813	2.075			
ENS 3	0.874	2.258			
ENS 4	0.865	2.326			
ENS 5	0.812	1.930			

Source: Authors

correlations. Table 3 shows that all HTMT ratios were less than the 0.9 threshold. As a result, the analysis indicates the discriminant validity of the model, that is, the constructs of the study are significantly different from each other.

5.3 Assessment of structural model

The PLS approach to SEM was used in this study to test the hypotheses pursuant to the methodology advised by Henseler *et al.* (2016). One of the principal advantages of PLS-SEM is its ability to generate adequate statistical power and accurate results even when samples are small, or data are not normally distributed. While covariance-based SEM seeks to minimize differences between the observed and the model-based covariance matrices, PLS-SEM endeavors to predict the value of dependent constructs through multiple regression analysis, as highlighted by Hair *et al.* (2019). Table 5 also presents the results of the PLS-SEM analysis. The t-values exceeding 1.96 indicate statistical significance at the 5% level, according to Hair *et al.* (2013). The PLS-SEM predictive performance was also measured by the out-of-sample predictive power. Positive Q^2 values are presented in Table 4, implying the model's predictive validity. Finally, Table 5 displays the f^2 effect sizes of each independent variable on the dependent variable, which is small (0.02), medium (0.15) or large (0.35), according to Chin *et al.* (2008). The f^2 values range from 0.014 to 0.558, indicating a small to large effect.

In addition, the model fit was tested based on the pre-specified Normed Fit Index (NFI) and the Standardized Root Mean Square Residual (SRMR) values. According to Garson (2016), "SRMR and NFI values below 0.08 and above 0.90 respectively signal excellent fit." In the present case, the SRMR was 0.061, and the NFI was 0.937, confirming an excellent model fit. It points to the fact that the data complies with the offered model, which further contributes to the credibility and accuracy of the findings.

To test the hypothesized relationships in the study, the authors conducted an analysis based on the PLS model. The outcomes that are principal for the analysis, such as path coefficients, p-values and t-values, are shown in Table 5. The validity of the hypotheses can be supported based on the statement that all relationships suggested by the conceptual model are statistically significant; this is justified by the p-values below 0.05.

Table 3 Discriminant validity

	ADE	COL	ENS	SCA	TA
ADE					
COL	0.647				
ENS	0.618	0.731			
SCA	0.547	0.615	0.655		
TA	0.853	0.631	0.608	0.538	

Source: Authors

Table 4 R^2, cross-validated redundancy (Q^2)

Construct	R^2	Q^2
ADE	0.345	0.390
COL	0.358	0.352
ENS	0.404	0.261
SCA	0.256	0.247

Source: Authors

6. Discussion on findings

The β coefficient (0.598, $p < 0.05$) for path TA →COL is positive, indicating that TA improves the level of COL among the diverse players in the HSCs. The use of collaborative platforms, real-time data sharing and communication tools have eliminated the existing silos, resulting in better coordination and integration across NGOs, government agencies and local communities. The findings are consistent with the study of Wamba *et al.* (2017). This result is in line with the DCV, which focuses on the importance of technological capabilities in enhancing organizational capabilities to adapt to and manage complex environments dynamically. Practically, humanitarian organizations should invest in technologies that can enable collaborative organization, given that they would better coordinate responses and, therefore, achieve more effective results in addressing an emergency.

The confirmation of *H2* ($\beta = 0.506$, $p < 0.05$) is established with the support that the application of advanced technologies in humanitarian supply directly contributes to their agility. The use of technology-based solutions such as AI for predictive analytics, IoT for real-time tracking and drones for fast delivery substantially shortens the reaction time to unexpected demand and supply fluctuations (Rodríguez-Espíndola *et al.*, 2020; Baharmand *et al.*, 2021). Agility becomes critical in disaster relief situations, where conditions can change with little notice. The discussion approves *H1*.

Support for *H3a* ($\beta = 0.539$, $p < 0.05$) and *H3b* ($\beta = 0.465$, $p < 0.05$) indicates that the dual value of collaboration: improved efficiency of aid delivery and ENS. COL can result in the optimized logistics processes, including shared transportation and storage. The findings align with the study of Moshtari (2016). Optimized logistics and storage will result in lower cost and time of aid delivery that would also ensure lower environmental impact. This is consistent with DCV, as the results suggest that the value of collaborative capability has a positive impact on sustainability performance.

The positive findings for *H4a* ($\beta = 0.159$, $p < 0.05$) and *H4b* ($\beta = 0.251$, $p < 0.05$) indicate that SCA improves the ADE and ENS. The result suggests, SCA changes their strategies immediately to adjust to the emergency situation, which helps successful distribution of resources and reduction in waste and redundancies. The findings support the DCV, according to which agility represents a dynamic capability allowing an organization to adapt to the changes in the environment rapidly while maintaining or even increasing the level of its performance and sustainability (Teece *et al.*, 2016).

The empirical support for *H5a*, *H5b* ($\beta = 0.323$ and $\beta = 0.278$, $p < 0.05$) and *H6a*, *H6b* ($\beta = 0.130$ and $\beta = 0.152$, $p < 0.05$) implies that the effects of TA on the ADE and ENS are mediated by the COL and SCA. Consequently, these empirical results demonstrate the essential mediating functions of the examined capabilities in establishing connections between technology and operational outcomes. Consequently, it is imperative to prioritize developing organizational capabilities along with the implementation of technology use, which

Table 5 Results of hypothesis testing

Hypothesis	Beta	*t*-statistics	*p*-value	F-square	Results
H1: **TA → COL**	0.598	17.96	0.000	0.558	Supported
H2: **TA → SCA**	0.506	9.379	0.000	0.343	Supported
H3a: **COL → ADE**	0.539	5.917	0.000	0.167	Supported
H3b: **COL → ENS**	0.465	6.232	0.009	0.136	Supported
H4a: **SCA → ADE**	0.159	6.575	0.000	0.014	Supported
H4b: **SCA → ENS**	0.251	9.631	0.000	0.035	Supported
H5a: **TA → COL → ADE**	0.323	5.333	0.000		Supported
H5b: **TA → COL → ENS**	0.278	5.766	0.000		Supported
H6a: **TA → SCA → ADE**	0.130	3.550	0.000		Supported
H6b: **TA → SCA → ENS**	0.152	4.421	0.000		Supported

Source: Authors' findings

allows firms to truly harness these technologies to achieve their goals. Hence, the discussion gives approval to hypotheses *H5a*, *H5b* and *H6a*, *H6b*.

6.1 Practical implications

This study has various practical implications. Organizations need to foster the advanced communication and data sharing technologies and train the project staff to ensure maximal adoption and benefits of the proposed technologies for all stakeholders in the humanitarian efforts. Training should be around skill building of data analysis, real-time decision-making and collaborative planning. The practice would help make use of the technological tools in breadth and depth, making them the catalyst for humanitarian operations and delivering solutions that are faster and based on best available data sources.

Humanitarian organizations also need to embrace new and emerging technologies that can increase the agility of their operations, thus making their responses to crisis more swift and efficient. Humanist organizations should invest in different modern technologies like AI, blockchain, drones, big data analytics and IoT. These technologies improve the information sharing capacity, the communication capability in real-time and enable predictive decision-making which can accommodate the requirements for the SCA and COL. This offers new possibilities, for example, AI to predict demand and optimize inventory levels and blockchain to provide transparency and traceability throughout the supply chain, reducing the risk of fraud and increasing trust with all stakeholders.

Similarly, humanitarian organizations are encouraged to build alliances and collaboratively approach for resources and capabilities sharing to raise the value of their relief work with lower environmental damage. To do it, humanitarian organizations need to prioritize investment in the professional development and maintenance of an agile-infrastructure capable of facing and adjusting to the unknowing dangers that humanitarian crises pose.

While it is essential to focus on adopting new technologies, it is equally vital to ensure that the organization's structures and culture enhance collaboration and agility. Organizations should develop training modules, altered management strategies and new operational procedures that promote flexibility and cooperation at all levels. Organizations must focus on the strategic investment in deploying technologies that promote collaboration and agility. Blockchain for transparency, drones for delivery to remote areas and IoT for real-time monitoring can increase the efficiency and responsiveness of humanitarian action.

Most importantly, the partnerships among NGOs, government bodies, local authorities and communities must be strengthened. Organizations should pursue formal agreements and collaborative frameworks that enable the sharing of resources and joint planning. Firms should develop agile practices for quickly responding to challenges, ranging from flexible logistics systems to scalable operational plans, which may improve the speed and sustainability of responses to emergencies.

6.2 Theoretical implications

The theoretical implications of this study are several, in a context of the DCV. DCV states that a firm's competitive advantage lies, in its ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments (Teece *et al.*, 1997). This research further operationalizes the DCV, showing that DCV in HSC can be realized via the double mediation of TA on COL and SCA.

Results of this study contribute to the DCV by adding the evidence that the integration of advanced technologies also incentivizes the formation of dynamic capabilities, such as a culture of collaboration and agility, in humanitarian settings. This study clarifies how such capabilities influence the relationship between technologies and operational outcomes, such as efficiency and sustainability, thus providing a nuanced understanding of capability development in crisis contexts. The research further expands the DCV of the firm, demonstrating that collaboration is a dynamic capability that improves the efficiency of aid distribution and ensures ENS. This study establishes that competent collaboration results in more efficient operations in terms of logistics, transportation and storage sharing, lowering the costs and the environmental impact. The results extend the research by Dubey *et al.* (2020, 2021) and Moshtari (2016), highlighting the strategic value of collaborative capabilities in complex operational environments.

The results of this study indicate that SCA plays a mediating role between TA and enhanced HSC performance. This finding is significant within the DCV framework, as it illustrates how agility as a key dynamic capability and enables organizations to quickly adjust their operations in response to changing needs and conditions. Real-time monitoring, predictive analytics and flexible logistics systems are supported by the technologies which enables humanitarian organizations to quickly and efficiently reshape their resources and processes, so they can deliver the necessary aid to the affected population (Baharmand *et al.*, 2021).

This study highlighted the role of DCV in achieving ENS in HSC context. This paper highlights how the adoption of green technologies and sustainable practices through advanced technology can harness dynamic capabilities to drive a reduction of the environmental footprint of humanitarian logistics. By doing so, it reinforces the DCV framework by identifying sustainability as a strategic objective driven by dynamic capabilities that aligns operational efficiency with environmental stewardship (Li *et al.*, 2019; Agyabeng-Mensah *et al.*, 2021).

7. Conclusion

This study aimed to investigate the implications of TA for improving the efficiency and sustainability of the humanitarian aid delivery process, with a focus on the mediating roles of collaboration and agility. The findings of this study indicate that technological improvements have a positive impact on COL and SCA within HSC, which subsequently enhances ADE and environmental stability. Therefore, these results can be used to expand academic knowledge in this field and provide practical guidance for humanitarian organizations dedicated to enhancing their response mechanisms when dealing with emergencies. This study answers two research questions, *RQ1*: Does TA improve ADE and ENS in humanitarian operations? And *RQ2*: Do COL and SCA mediate the relationship between TA, ADE and ENS? Results from this study verified that TA significantly and positively affects ADE and ENS. The confirmation of this relationship was an indication that the use of advanced technologies such as AI, IoT and drones are central to enhancing efficiency functions and cutting on ENS.

To answer *RQ2*, this study empirically confirms that COL and SCA significantly mediate the outcomes of TA to improve efficiency in aid delivery and ENS. Therefore, the mediating role emphasizes the need for the creation of the organizational capacity that strengthens collaboration and operational agility. By integrating the research framework with and DCV, this study expands the capacities of existing theoretical paradigms to focus on the strategic resource realized through technology. This research confirms that TA is not only about use but also about the realization of the key capabilities of collaboration and agility that enable firms to optimize the use of technological advantages.

Like various other studies, this study also has few limitations: first, the data is cross-sectional in nature; future research could attempt to conduct longitudinal studies to analyze how TA influences HSC performance in long term. Second, data is collected from the humanitarian organizations based in India; researchers should keep this in mind while using the findings from this study. A cross-cultural study by taking data from other emerging economy may be conducted to compare the findings of the study.

Outcomes could be further studied for the individual effect of breakthrough technologies like blockchain, AI, drones and IoT in different aspects of HSC. By isolating the effects of individual technologies, researchers can provide more detailed recommendations on their deployment and integration into humanitarian operations. Future research opportunities include examining the inter-organizational dynamics afforded through the adoption of technology. This will involve investigation of how technologies impact power relations, trust creation and governance arrangements between different actors in the HSC. These dynamics are key to supporting collaboration with technology specifically and can allow for more strategic deployment of technology for collaborative investments.

References

Agyabeng-Mensah, Y., Afum, E., Acquah, I.S.K., Dacosta, E., Baah, C. and Ahenkorah, E. (2021), "The role of green logistics management practices, supply chain traceability and logistics ecocentricity in sustainability performance", *The International Journal of Logistics Management*, Vol. 32 No. 2, pp. 538-566.

Altay, N. and Green, W.G. III. (2006), "Or/MS research in disaster operations management", *European Journal of Operational Research*, Vol. 175 No. 1, pp. 475-493.

Altay, N., Gunasekaran, A., Dubey, R. and Childe, S.J. (2018), "Agility and resilience as antecedents of supply chain performance under moderating effects of organizational culture within the humanitarian setting: a dynamic capability view", *Production Planning & Control*, Vol. 29 No. 14, pp. 1158-1174.

Bag, S., Luthra, S., Venkatesh, V.G. and Yadav, G. (2020), "Towards understanding key enablers to green humanitarian supply chain management practices", *Management of Environmental Quality: An International Journal*, Vol. 31 No. 5, pp. 1111-1145.

Bag, S., Rahman, M.S., Srivastava, G., Giannakis, M. and Foropon, C. (2023), "Data-driven digital transformation and the implications for antifragility in the humanitarian supply chain", *International Journal of Production Economics*, Vol. 266, p. 109059.

Baharmand, H., Maghsoudi, A. and Coppi, G. (2021), "Exploring the application of blockchain to humanitarian supply chains: insights from humanitarian supply blockchain pilot project", *International Journal of Operations & Production Management*, Vol. 41 No. 9, pp. 1522-1543.

Beamon, B.M. and Balcik, B. (2008), "Performance measurement in humanitarian relief chains", *International Journal of Public Sector Management*, Vol. 21 No. 1, pp. 4-25.

Chari, F. and Novukela, C. (2023), "The influence of information and communication technologies on disaster relief operations: a case of cyclone Idai in Zimbabwe", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 13 No. 4, pp. 399-409.

Chin, W.W., Peterson, R.A. and Brown, S.P. (2008), "Structural equation modeling in marketing: some practical reminders", *Journal of Marketing Theory and Practice*, Vol. 16 No. 4, pp. 287-298.

Comes, T., Bergtora Sandvik, K. and Van de Walle, B. (2018), "Cold chains, interrupted: the use of technology and information for decisions that keep humanitarian vaccines cool", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 8 No. 1, pp. 49-69.

DHL (2024), "DHL warehouse of the future", autonomous vehicle technologies guide", available at: www.dhl.com/content/dam/dhl/global/csi/documents/pdf/glo-csi-auto-mobility-innovation-wallet-automation.pdf (accessed on 15 April 2024).

Dubey, R., Gunasekaran, A., Bryde, D.J., Dwivedi, Y.K. and Papadopoulos, T. (2020), "Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting", *International Journal of Production Research*, Vol. 58 No. 11, pp. 3381-3398.

Dubey, R., Bryde, D.J., Foropon, C., Graham, G., Giannakis, M. and Mishra, D.B. (2022), "Agility in humanitarian supply chain: an organizational information processing perspective and relational view", *Annals of Operations Research*, Vol. 319 No. 1, pp. 559-579.

Dubey, R., Bryde, D.J., Foropon, C., Tiwari, M., Dwivedi, Y. and Schiffling, S. (2021), "An investigation of information alignment and collaboration as complements to supply chain agility in humanitarian supply chain", *International Journal of Production Research*, Vol. 59 No. 5, pp. 1586-1605.

DWB (2017), "Drones as a humanitarian tools", available at: www.doctorswithoutborders.org/latest/drones-humanitarian-tools (accessed on 15 April 2024).

Edwards, D., Subramanian, N., Chaudhuri, A., Morlacchi, P. and Zeng, W. (2023), "Use of delivery drones for humanitarian operations: analysis of adoption barriers among logistics service providers from the technology acceptance model perspective", *Annals of Operations Research*, Vol. 335 No. 3, pp. 1-23.

Ehsani, B., Karimi, H., Bakhshi, A., Aghsami, A. and Rabbani, M. (2023), "Designing humanitarian logistics network for managing epidemic outbreaks in disasters using internet-of-Things. A case study: an earthquake in Salas-e-Babajani city", *Computers & Industrial Engineering*, Vol. 175, pp. 108821.

Eisenhardt, K.M. and Martin, J.A. (2000), "Dynamic capabilities: what are they?", *Strategic Management Journal*, Vol. 21 No. 10, pp, 1105-1121.

Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*,) Vol. 18 No. 1, pp. 39-50.

Garson, G.D. (2016), "Partial least squares (PLS-SEM): 2016 edition", *Statistical Associates Publishing*, *Asheboro*.

Grange, R., Heaslip, G. and McMullan, C. (2020), "Coordination to choreography: the evolution of humanitarian supply chains", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 10 No. 1, pp. 21-44.

Grigoli, G.D.A., Silva Júnior, M.F.D. and Pedra, D.P. (2024), "Challenges and perspectives for humanitarian logistics: a comparative study between the democratic republic of Congo, the Central African Republic and the republic of South Sudan", *Journal of Humanitarian Logistics and Supply Chain Management*, doi: 10.1108/JHLSCM-07-2022-0087.

Hair, J.F., Tatham, R.L., Anderson, R.E. and Black, W. (2006), *Multivariate Data Analysis*, Vol. 6, Pearson Prentice Hall, Upper Saddle River, NJ.

Hair, J.F., Ringle, C.M. and Sarstedt, M. (2013), "Partial least squares structural equation modeling: rigorous applications, better results and higher acceptance", *Long Range Planning*, Vol. 46 Nos 1/2, pp. 1-12.

Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019), "When to use and how to report the results of PLS-SEM", *European Business Review*, Vol. 31 No. 1, pp. 2-24.

Henseler, J., Hubona, G. and Ray, P.A. (2016), "Using PLS path modeling in new technology research: updated guidelines", *Industrial Management & Data Systems*, Vol. 116 No. 1, pp. 2-20.

Henseler, J., Ringle, C.M. and Sarstedt, M. (2015), "A new criterion for assessing discriminant validity in variance-based structural equation modeling", *Journal of the Academy of Marketing Science*, Vol. 43 No. 1, pp. 115-135.

Iqbal, T. and Ahmad, S. (2022), "Transparency in humanitarian logistics and supply chain: the moderating role of digitalisation", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 12 No. 3, pp. 425-448.

Kabra, G., Ramesh, A. and Arshinder, K. (2015), "Identification and prioritization of coordination barriers in humanitarian supply chain management", *International Journal of Disaster Risk Reduction*, Vol. 13, pp. 128-138.

Kovács, G. and Spens, K.M. (2007), "Humanitarian logistics in disaster relief operations", *International Journal of Physical Distribution & Logistics Management*, Vol. 37 No. 2, pp. 99-114.

L'Hermitte, C., Tatham, P., Brooks, B. and Bowles, M. (2016), "Supply chain agility in humanitarian protracted operations", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 6 No. 2, pp. 173-201.

Li, C., Zhang, F., Cao, C., Liu, Y. and Qu, T. (2019), "Organizational coordination in sustainable humanitarian supply chain: an evolutionary game approach", *Journal of Cleaner Production*, Vol. 219, pp. 291-303.

Logistics Cluster (2018), "This is logistics cluster preparedness", available at: https://logcluster.org/en/preparedness (accessed on 15 April 2024).

Modgil, S., Singh, R.K. and Hannibal, C. (2022a), "Artificial intelligence for supply chain resilience: learning from covid-19", *The International Journal of Logistics Management*, Vol. 33 No. 4, pp. 1246-1268.

Modgil, S., Singh, R.K. and Foropon, C. (2022b), "Quality management in humanitarian operations and disaster relief management: a review and future research directions", *Annals of Operations Research*, Vol. 319 No. 1, pp. 1045-1098.

Moshtari, M. (2016), "Inter-organizational fit, relationship management capability, and collaborative performance within a humanitarian setting", *Production and Operations Management*, Vol. 25 No. 9, pp. 1542-1557.

Mukhopadhyay, S., Singh, R.K. and Jain, T. (2024), "Developing artificial intelligence enabled marketing 4.0 framework: an industry 4.0 perspective", *Qualitative Market Research: An International Journal*.

Najjar, M.S., Dahabiyeh, L. and Nawayseh, M. (2019), "Share if you care: the impact of information sharing and information quality on humanitarian supply chain performance", *A Social Capital Perspective. Information Development*, Vol. 35 No. 3, pp. 467-481.

OCHA (2021), "Global humanitarian overview", available at: https://2021.gho.unocha.org/ (accessed on 15 April 2024).

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, p. 879.

Rodríguez-Espíndola, O., Chowdhury, S., Beltagui, A. and Albores, P. (2020), "The potential of emergent disruptive technologies for humanitarian supply chains: the integration of blockchain, artificial intelligence and 3D printing”, *International Journal of Production Research*, Vol. 58 No. 15, pp. 4610-4630.

Saari, S. (2023), “Enhancing the environmental sustainability of emergency humanitarian medical cold chains with renewable energy sources”, *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 13 No. 2, pp. 157-172.

Santarelli, G., Abidi, H., Klumpp, M. and Regattieri, A. (2015), “Humanitarian supply chains and performance measurement schemes in practice”, *International Journal of Productivity and Performance Management*, Vol. 64 No. 6, pp. 784-810.

Sharma, A., Bhatia, T., Singh, R.K. and Sharma, A. (2024), “Developing the framework of blockchain-enabled Agri-food supply chain”, *Business Process Management Journal*, Vol. 30 No. 1, pp. 291-316.

Sharma, A., Sharma, A., Singh, R.K. and Bhatia, T. (2023), “Blockchain adoption in Agri-food supply chain management: an empirical study of the main drivers using extended UTAUT”, *Business Process Management Journal*, Vol. 29 No. 3, pp. 737-756.

Singh, R.K. (2024a), “Wheeling towards sustainability: the nexus of external pressures, green innovation, and circular supply chain excellence”, *Business Process Management Journal*, Vol. 30 No. 4, doi: 10.1108/BPMJ-10-2023-0772.

Singh, R.K. (2024b), “Impact of leadership, TQM and supply chain capabilities on sustainable supply chain performance: moderating role of institutional pressure”, *The TQM Journal*, doi: 10.1108/TQM-09-2023-0275.

Singh, R.K. and Acharya, P. (2013), “Supply chain flexibility: a framework of research dimensions”, *Global Journal of Flexible System Management*, Vol. 14 No. 3, pp. 157-166.

Singh, R.K. and Acharya, P. (2014), “Identification and evaluation of supply chain flexibilities in Indian FMCG sector using DEMATEL”, *Global Journal of Flexible Systems Management*, Vol. 15 No. 2, pp. 91-100.

Singh, R.K. and Joshi, H.T. (2024), “Greening the supply chain: institutional pressures, Data-driven innovations, and the road to circular sustainability”, *Business Strategy and the Environment*, doi: 10.1002/bse.3788.

Singh, R.K. and Modgil, S. (2024), “Impact of information system flexibility and dynamic capabilities in building net zero supply chains”, *Journal of Enterprise Information Management*, Vol. 37 No. 3, doi: 10.1108/JEIM-09-2023-0477.

Singh, R.K., Modgil, S. and Acharya, P. (2019), “Assessment of flexible supply chain using system dynamics modelling: a case of Indian soap manufacturing firm”, *Global Journal of Flexible System Management*, Vol. 20 No. 1, pp. 39-63.

Singh, R.K., Mathiyazhagan, K., Scuotto, V. and Pironti, M. (2024), “Green open innovation and circular economy: investigating the role of big data management and sustainable supply chain”, *IEEE Transactions on Engineering Management*, Vol. 71, doi: 10.1109/TEM.2024.3387107.

Srivastava, S.K. and Bag, S. (2023), “Recent developments on flexible manufacturing in the digital era: a review and future research directions”, *Global Journal of Flexible Systems Management*, Vol. 24 No. 4, pp. 483-516.

Teece, D.J., Pisano, G. and Shuen, A. (1997), “Dynamic capabilities and strategic management”, *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-533.

Teece, D., Peteraf, M. and Leih, S. (2016), “Dynamic capabilities and organizational agility: risk, uncertainty, and strategy in the innovation economy”, *California Management Review*, Vol. 58 No. 4, pp. 13-35.

Vangen, S. and Huxham, C. (2010), “Introducing the theory of collaborative advantage”, *The New Public Governance*?, pp. 179-200, Routledge.

Wamba, S.F., Gunasekaran, A., Akter, S., Ren, S.J.F., Dubey, R. and Childe, S.J. (2017), “Big data analytics and firm performance: effects of dynamic capabilities”, *Journal of Business Research*, Vol. 70, pp. 356-365.

WFP (2017), “Building blocks: blockchain network for humanitarian assistance”, available at: https://innovation.wfp.org/project/building-blocks# (accessed on 15 April 2024).

Further reading

Kabra, G. and Ramesh, A. (2015), “An empirical investigation of the enablers in humanitarian supply chain management in India: a case study”, *Journal of Advances in Management Research*, Vol. 12 No. 1, pp. 30-42.

Schumann-Bölsche, D. (2018), “Information technology in humanitarian logistics and supply chain management”, *The Palgrave Handbook of Humanitarian Logistics and Supply Chain Management*, pp. 567-590.

Shrivastav, S.K. and Bag, S. (2023), *Humanitarian Supply Chain Management in the Digital Age: A Hybrid Review Using Published Literature and Social Media Data*, An International Journal, Benchmarking, doi: 10.1108/BIJ-04-2023-0273.

Appendix

Table A1 Construct and measures

Construct	Item no.	Measures	Source
Technology adoption (TA)	TA1	Tech-enabled predictive analytics, forecasting and decision making (AI)	Edwards *et al.* (2023); Wamba *et al.* (2017)
	TA 2	Technology implementation for transparency and traceability (Blockchain)	
	TA 3	Technology for deliveries and assessment purposes (Drones)	
	TA 4	Technology for logistics and operations planning (BDA)	
Collaboration (COL)	COL 1	Information sharing frequency	Moshtari (2016)
	COL 2	Joint decision-making	
	COL 3	Resource sharing	
	COL 4	Collaborative planning frequency	
	COL 5	Integration of efforts	
Supply chain agility (SCA)	SCA 1	Respond speed to demand change	Dubey *et al.* (2020); Altay *et al.* (2018)
	SCA 2	Robust network of suppliers	
	SCA 3	Operation’s scalability	
	SCA 4	Recovery speed from disruption	
	SCA 5	Capability to handle sudden changes	
Aid delivery efficiency (ADE)	ADE 1	Delivery lead time	Santarelli *et al.* (2015); Kovács and Spens (2007)
	ADE 2	Delivery accuracy	
	ADE 3	Cost per delivery	
	ADE 4	Volume of aid delivery	
Environmental sustainability (ENS)	ENS 1	Waste management	Singh and Modgil (2024); Singh (2024a,b); Singh *et al.* (2024)
	ENS 2	Carbon footprint	
	ENS 3	Energy efficiency	
	ENS 4	Water use	
	ENS 5	Sustainable sourcing	

Source: Authors

Table A2 Respondent profile

Variable	Classification	Frequency	%
Experience (Years)	< 10 years	83	29
	10–20 years	124	43
	>20 years	82	28
Domain of Work	Executive leadership	14	5
	Logistics managers	26	9
	Supply chain coordinators	29	10
	Field operations managers	42	15
	Program directors	11	4
	IT team	19	7
	Supply chain consultant	55	19
	Sustainability team	27	9
	Environmental consultant	21	7
	Disaster relief team	30	10
	Distribution	15	5
Industry	Disaster relief organizations	56	14
	NGOs	92	16
	ICT companies	39	28
	Government agencies	22	10
	Logistics and transportation firms	80	8
	Pharmaceutical companies	40	24
Role in company	Senior management	92	32
	Middle-level management	197	68

Source: Authors

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