Barriers to Information and Digital Technologies Adoption in Humanitarian Supply Chain Management: A Fuzzy AHP Approach

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Abstract

Purpose: The humanitarian supply chain (HSC) area is rich with conceptual frameworks with a focus on the importance of information and digital technologies (IDTs) applications. These frameworks have a limited scope in investigating and prioritizing barriers to IDTs adoption in HSCs. The present study thus identifies and prioritizes the barriers to IDTs adoption in organizations involved in HSCs.

Design/methodology/approach: By using a literature review allied with expert discussions and a fuzzy analytic hierarchy process, the study identifies and prioritizes a comprehensive set of barriers that organizations involved in HSCs may consider to improve IDTs adoption.

Findings: The study investigates five main barriers (strategic, organizational, technological, financial and human) interlocked with 25 sub-barriers impacting the level of IDTs adoption in organizations involved in HSCs. The findings indicate that strategic barriers are of greatest importance, followed by organizational, technological, financial and human barriers. The findings indicate the difference in ranking barriers influencing the adoption of IDTs in HSCs compared to the commercial supply chain.

Research limitations/implications: Although a three-step method adopted for this study is rigorous in terms of the way this research is conducted, it is essential to report that prioritization is based on the subjective opinions of the experts.

Practical implications: The findings aim to assist policymakers and practitioners in developing effective strategies to improve IDTs adoption in organizations engaged in HSCs. Moreover, the prioritization of barriers provides a systematic way to overcome any barriers to improve HSCs performance.

Originality/value: This study is the first of its kind that investigates and prioritizes the barriers to IDTs adoption in HSCs.

Keywords: Analytical hierarchy process; Humanitarian supply chain performance; Information Technology; Fuzzy logic.

Paper type: Research paper

Introduction

Disasters are inevitable, but preventive measures may lessen social and economic losses caused by disasters (Cao et al., 2021; Yılmaz and Kabak, 2020). A supply chain approach is required for a quick and effective response in the aftermath of disasters (Dubey et al., 2019; Lewin et al., 2018, John et al., 2019). The objective of commercial supply chains (CSCs), such as carrying the "right supplies" at the "right time" to the "right area" in the "right quantities" to the "right people" (Petrudi et al., 2019), is applicable in humanitarian supply chains (HSCs). However, unlike CSCs, HSCs operate under highly complex, uncertain and challenging environments (Akhtar et al., 2020; Tomasini and Wassenhove, 2009). To this end, adopting information and digital technologies (IDTs) may improve organizational performance in HSCs (Marić et al., 2021).

Digital technologies, including computing, information, communication and connectivity technologies (Bharadwaj et al., 2013), are transforming the business models of commercial supply chains. Similarly, technologies such as global positioning systems, early warning systems and geographic information systems can improve the performance of HSCs (Özdamar and Ertem, 2015; Rodríguez-Espíndola et al., 2020). Also, social networking websites such as Facebook and Twitter collectively build and disseminate vital information about disasters to society (Kankanamge et al., 2020; Searle, 2020). In this context, the adoption of IDTs becomes crucial (Jung and Jung, 2018); however, the unique context of HSCs poses many challenges to IDTs adoption (Baharmand et al., 2021).

Several challenges impede maximum utilization of technology to connect end-to-end humanitarian operations (i.e. from donors to affected consumers) (Coppi, 2018). The challenges range from strategic issues, to organizational issues to individual issues (Maiers et al., 2005). The challenges include lack of availability of funds, lack of IT experts (Kabra and Ramesh, 2015a), conflicting short-term-oriented culture in place of long-term commitment, lack of information (Negi and Negi, 2020) and limited technological infrastructure. Further, Cook and Picucci (2017) reported governance as the major challenge in using robots in disaster management. These challenges affect the whole system, especially interlinked activities between horizontal and vertical operations among organizations involved in HSCs (Kabra and Ramesh, 2016a).

Despite the promising benefits of IDTs for organizations involved in HSCs, social and behavioral research reports low utilization of information technology (Negi and Negi, 2020).

Extant research tends to focus on isolated technologies in HSCs. These include big data (Dubey et al., 2019), radio frequency identification (Yang et al., 2011), sensors (Alamdar et al., 2017), IoT (Sinha et al., 2019), and blockchain technology (Dubey et al., 2020). Sahebi et al. (2020) have analyzed blockchain barriers in HSCs using the best-worst method while Kabra and Ramesh (2017) focus on the relationship between the enablers to information and communication technology. These studies consider only a segment of the range of emerging technologies or set of few enablers in the context of HSCs. Therefore, there is a lack of research that considers the comprehensive set of barriers influencing IDTs adoption in those organizations involving HSCs.

The instant removal of all barriers influencing IDTs adoption in organizations involved in HSCs is impossible due to limited resources in terms of finance, capital and personnel allied with time constraints. Therefore, it is imperative to establish the relative importance of barriers to systematically improve the utilization of IDTs. To the best of the author's knowledge, there is a lack of studies examining the relative importance of relevant barriers. Consequently, to assist the organizations engaged in HSC and to endeavour to bridge the knowledge gap, this study identifies and prioritizes barriers to IDTs adoption in HSCs. The study combines a literature review with expert discussions to investigate five main barriers (strategic, organizational, technological, financial and human) interlocked with 25 sub-barriers. The barriers are then prioritized using the fuzzy analytic hierarchy process (F-AHP) method.

The subsequent Section explains the IDTs adoption barriers in HSCs. Section 3 and 4 present the research methodology and illustrate the application of the method, respectively. Section 5 presents the discussion and implications of the study. Finally, Section 6 present the conclusion, including limitations and possible directions for future research.

2. Literature review

The COVID pandemic has significantly impacted CSCs and HSCs. For instance, the lack of availability of alternative suppliers has disturbed the entire production line. Resulting unemployment is responsible for a reduction in consumption and irrational buying behavior of many consumers (Kovács and Sigala, 2021). Studies have reported many global challenges for the humanitarian supply chain in extant literature. Such challenges include unpredictability about disaster occurrence, irregular supply and demand and requirements for immediate relief supplies (Aringhieri et al., 2017). Kovács and Spens (2009) reported challenges to HSCM as "*lack of vehicles, low use of advanced ICT technologies, lack of communication, lack of*

supplies, lack of equipment, difficulties in enforcing standards, lack of knowledge of humanitarian organizations, brain drain, lack of governance, dependence on government declaring a state of emergency, lack of transport infrastructure, lack of early warning systems, absence of legislation, security problems, lack of coordination". There are also huge challenges to be faced in humanitarian operations depending on the scale of devastation and disaster types (Kovács and Spens, 2009).

Academicians, practitioners and policymakers have been arguing that information technology adoption in HSCs may improve the performance of humanitarian operations (Buddas, 2014; Delmonteil and Rancourt, 2017). For example, information systems for information sharing may prove helpful in critical tasks such as transportation, logistics and procurement of relief materials (Pettit and Beresford, 2009). Similarly, aerial robotics, including unmanned aerial vehicles (UAVs), can assess the situation at a disaster site in real-time to improve humanitarian operational performance. However, the adoption of IT by organizations involved in HSCM is still not at the forefront of operations (Kabra and Ramesh, 2015a). The effective utilization of IT in HSCs is hampered due to several barriers rooted in multi-disciplinary domains. These barriers are not only technological, but are also often part of organizational issues linked with culture, mission and top management commitment (Maiers et al., 2005).

The technology adoption process in organizations involved in HSCs involves change and change management; some challenges may be anticipated in advance due to such transition. These hurdles result in barriers influencing the adoption of the technology adoption process in HSCs. The barriers require immediate attention at the initial stage to smooth the technology adoption process in HSCs. Also, technology adoption requires analysis from different angles, such as organization technical capacity. This study considers only those papers that have considered disaster relief operations from the supply chain perspective i.e., humanitarian supply chain. The study has utilized the following academic databases to search related literature: Scopus, Web of Science, ScienceDirect, Emerald, Google Scholar and Ebsco. The study begins with a search of papers using selected query keywords: "big data" or "blockchain" or "technology" or "cloud computing" or "Information and communications technology" or "ICT*" or "Information and communication*" or "information technology" or "information systems" AND "Internet of things" or "humanitarian supply chain" or "humanitarian supply*" or "humanitarian operations*" or "disaster operations*" or "relief supply chain" or "humanitarian logistics". The keywords are identified after discussion with leading scholars in

the area of the humanitarian supply chain. Only papers that have been written in the "English" language are included. With this search, articles have been obtained that address the challenges to adopting IDTs in HSCs. The articles include conceptual papers, case studies, qualitative studies and literature reviews. The challenges are categorized into five groups as discussed in the next section.

2.1 Barriers to IDT adoption in HSCs

There is a lack of research aimed at understanding the barriers to IDTs adoption, so initial examination of the barriers is supplemented by expert discussions. The barriers are classified into five main areas (strategic, organizational, technological, financial and human) duly verified by a group of experts, as explained below.

2.1.1 Strategic barriers (SB)

Strategic barriers are related to the strategic aspect of the IDTs adoption by organizations involved in the HSCs. Organizations need extra funds, efforts, and time to adopt IDTs. The process of IDT adoption in organizations involved in HSCs requires strong leadership and top management commitment. However, it has been recognized that technology adoption is not top management's priority (Maiers et al., 2005). The following barriers fall under the category of strategic barriers.

Lack of policies to adopt technology (SB1): There is a lack of policy at the organization level towards adopting IDTs. Organizations involved in HSCs generally work in silos; they hardly ever share information with other organizations in the disaster preparedness phase (Petrudi et al., 2019). The resistive behavior of organizations towards information sharing (Kabra, 2017; Patil et al., 2021) often complicates the development of policy at organization level.

Inadequate policy awareness and support from the government (SB2): Organizations involved in HSCs are not fully aware of government policies that support facilitating IDT adoption. This includes support in generating funds, training and knowledge gathering (Kabra and Ramesh, 2015a).

Lack of management vision (SB3): The process of IDTs implementation requires support from top management. However, the adoption of IDT is not amongst management's top priorities. Top management is not fully aware of the benefits of technology in HSCs, particularly advanced applications such as big data applications, the use of the internet of things and drone

deployment (Vogt et al., 2011). Moreover, top management of many organizations involved in HSCs regard investment in IT systems as an overhead cost.

Lack of cross-organization development program (SB4): There is a lack of coordination and collaboration with commercial organizations to improve IDT adoption by organizations involved in HSCs. Subsequently, there is a lack of cross-organization development programs with potentially valuable partners in the commercial sector (Nurmala et al., 2017).

Lack of supply chain understanding (SB5): The supply chain is the backbone of any relief operation regardless of the scale and geographic location of the disaster. However, knowledge about the role of supply chain management and its links with technology is minimal in many organizations involved in HSCs (Gustavsson, 2003; Kabra and Ramesh, 2015a). Kabra (2017) also pointed out that the lack of supply chain understanding complicates the performance of organizations engaged in HSCs.

2.1.2 Organization barriers (OB)

Organizational barriers are related to structural issues such as lack of pressure from other organizations and short-term goal-oriented thinking. The use of technology improves information sharing between organizations involved in HSCs (Kabra and Ramesh, 2016b; Lee and Zbinden, 2003). However, the differences in organizations' objectives impacts the process of IDT adoption. Thus, this forms the basis of the organization's barriers. The following barriers fall under the category of organization barriers.

Conflicting short-term focus goal-oriented culture (OB1): Organizations involved in HSCs work only during the disaster response phase. They have no interest in long-term improvement in the disaster preparedness phase (Kabra and Ramesh, 2015a; Maiers et al., 2005).

Not inviting end-user input (OB2): Experts have pointed out that the end-user's involvement is minimal in making decisions to improve the performance of many organizations. The process of IDT adoption requires input from the end-user.

Lack of IT personnel (OB3): Organizations involved in HSCs lack skilled IT personnel in their workforces (Kabra, 2017).

Lack of pressure from other organizations (OB4): Experts point out a lack of pressure from other organizations working to better the humanitarian operations to improve utilization of IDTs.

Lack of transparency in the utilization of funds (OB5): Donors ideally look for transparent and scalable utilization of funds (Oloruntoba and Gray, 2009). Organizations are responsible for maintaining transparency in utilizing funds received from donors. However, organizations lack the systems needed to show proper utilization of funds at micro-levels (Maiers et al., 2005).

2.1.3 Technology barriers (TB)

Technological barriers refer to limited access to appropriate software and hardware to improve work efficiency. These barriers are related to poor awareness of infrastructure. Odedra-Straub (1993) concluded that poor IT infrastructure issues in developing countries are the key reasons why humanitarian organizations cannot gather sufficient information for effective coordination.

Lack of awareness about exact technological solutions (TB1): Organizations involved in HSCs lack problem-specific technological solutions (Vogt et al., 2011).

Lack of IT enabling infrastructure (TB2): The role of technology in relief operations is crucial. However, traditional terrestrial technology infrastructures need an update in the current scenario (Delmonteil and Rancourt, 2017). Infrastructure needing revision includes hardware, software and better trained IT staff.

Lack of customization (TB3): Humanitarian operations require specific technology applications customized to the activities in the context of HSCs (Gavidia, 2017). Standard commercial packages do not cater for the needs of humanitarian operations (Falagara Sigala et al., 2020). Customized disaster response applications, on the other hand, are either unavailable or prohibitively expensive.

Frequent updates of technology (TB4): IT and driven applications are continuously changing and updating (Sahebi et al., 2020). Constant update requires a significant investment of resources and further complicates the process of satisfying the donor.

Incompatibility in IT facilities linked with different organizations (TB5): The utilization of technology goes through a series of stages, starting from IT adoption in an umbrella

organization to its supply chain processes linked with other interconnected organizations. Compatibility among stakeholders is essential, with effective IT implementation bringing all of them onto the same platform through appropriate integration and information sharing (Vogt et al., 2011). However, humanitarian organizations lack such integration, and their differences in available facilities are significant hurdles.

2.1.4 Finance barriers (FB)

An organization's ability to adopt technology into their operations, to a large extent, depends on the availability of financial resources. Those organizations involved in HSCs need funds to improve all aspects of their operations (Burkart et al., 2016). Funding improves the effectiveness and efficiency of humanitarian organizations in relief operations (Wakolbinger and Toyasaki, 2014). Thomas (2003) reported that donor behavior is among the major stumbling blocks that prevent humanitarian actors from developing processes and systems to improve HSCs performance. The following fall under the category of finance barriers.

Donor support (FB1): Donor support is the backbone for any relief operations (Burkart et al., 2016). It has been noted that donor support is available after the disaster (Sandwell, 2011); donors do not support IDTs adoption in the preparedness phase (Maiers et al., 2005). Donors are hesitant to provide funds for enhancing advanced facilities needed for technology utilization (Oloruntoba and Gray, 2006).

Lack of funds for investment in technology (FB2): Organizations suffer from the unstable nature of funding (Aflaki and Pedraza-Martinez, 2016; Oloruntoba and Gray, 2006). Moreover, many organizations receive only in-kind donations such as food supplies and clothes. These organizations do not receive money to invest in the IT process. The preference of donors for short-term improvement compared to long-term planning processes further complicates the performance of HSCs (Ibegbunam and McGill, 2012; Tomasini and Van Wassenhove, 2009). Thus, there is a lack of investment in technology in organizations involved in HSCs (Gustavsson, 2003).

High Cost (FB3): There is a high cost involved in adopting suitable technology (Delmonteil and Rancourt, 2017). Funds are required at different phases of adoption. Kapucu and Garayev (2012) also showed that effective utilization of IT calls for more investment in IT infrastructure and advanced technology that humanitarian organizations lack.

Competition for funding (FB4): There is an increase in the number of organizations working to alleviate human suffering after a disaster. The increase in the number of organizations leads to intense competition in generating funds (Wakolbinger and Toyasaki, 2014).

Fundraising expenses (FB5): Funding systems involve multiple stakeholders with different objectives (Wakolbinger and Toyasaki, 2014). The expenses incurred to acquire funds from different funding agencies and donors is high in the context of HSCs.

2.1.5 Human *barriers (HB)*

Human barriers are related to psychological issues such as needs, expectations and individual concern towards organizational change. Expert discussions further reveal that organizations involved in HSCs operating in developing countries lag far behind compared to developed countries in terms of education, funding and equipment to improve their response to disasters (Van Wassenhove, 2006). Human factors are crucial for the success of any HSCs (De Camargo et al., 2021). The following are categorized as human barriers.

Lack of skills to use IT (HB1): The workforce often lacks essential IT skills to use IDTs such as satellite technology (Delmonteil and Rancourt, 2017). Staff lack IT adoption knowledge and experience working with appropriate software needed to generate valuable insights from advanced structured and unstructured data that contribute to operational performance (Kabra, 2017).

Lack of education and training for employees (HB2): The transfer of information and instant decision-making skills requires training for employees tasked with improving the performance of HSCs (Kabra, 2017). Similarly, continuous improvement through training is vital to support the process of IDT adoption. However, employees working in organizations involved in HSCs do not have sufficient training opportunities to build on their skills (Patil et al., 2021).

Lack of benchmarking about knowledge of IT (HB3): Experts pointed out that benchmarking about knowledge of IT in HSCs is not available.

Workforce resistance to change (HB4): Employees are used to working in an established system and are wary of any structural changes for fear of having to learn new skills. Lack of benchmarking about knowledge of IT leads to workforce resistance to take on new ideas; they are not sure about the efforts required to gain the knowledge needed for new IT systems.

Lack of motivation to use IT (HB5): Employees, mainly working in organizations involved in HSCs, are critical stakeholders in relief operations (Agostinho, 2013). However, they are unaware of the benefits that can significantly increase their decision-making to make faster and more effective decisions linked with front-line needs (Vogt et al., 2011). Employees are not motivated to use IT in their work. The negative perception and the fear of losing their jobs contribute to a lack of willingness to adopt IT and its use.

The literature review highlights technology adoption barriers in the CSCs (Akhtar et al., 2018; Hoque and Sorwar, 2017). However, barriers to technology adoption in HSCs differ from CSCs in many ways. These include the availability of resources, unpredictability about the occurrence of the disaster and different organizational structures in HSCs (Oloruntoba and Kovács, 2015; Tomasini and Van Wassenhove, 2009). Moreover, design and formation activities in HSCs are more complex than in CSCs (Dubey et al., 2020; Queiroz et al., 2020). The related issues differ across industries and countries. These differences may be due to the spectacular growth in IDTs and changes in government policies. In India, it is crucial to innovate and implement IDTs to improve performance of humanitarian operations. Some researchers have attempted to examine the adoption of IDTs issues in the Indian context but no studies are available that prioritize the barriers to IDT adoption in HSCs. Existing literature only focuses on the role and importance of technology in HSCs. It investigates barriers from the view of isolated technologies such as satellites (Delmonteil and Rancourt, 2017) or blockchain (Sahebi et al., 2020). Therefore, this study is a unique attempt to investigate and analyze the strength of barriers to IDT adoption in HSCs. The current study adopts a rigorous procedure by considering expert opinions to examine the strength of barriers to IDT adoption in HSCs in the Indian context.

3. Research Methodology

The study adopts a systematic review methodology (Tranfield et al., 2003) allied with expert discussion to examine the barriers influencing IDTs adoption in organizations involved in HSCs. A team of six experts have taken part to achieve the study's objectives. The team includes technology developers, supply chain experts, IT experts and academic scholars. Details of the experts are given in Table 1. Studies based on multicriteria decision-making methods (MCDM) have recently gained attention in HSC due to their practical relevance (Venkatesh et al., 2019). Important papers have been written on supply partner selection in HSC (Venkatesh et al., 2019), humanitarian housing projects (El-Anwar et al., 2010),

temporary shelter location selection (Nappi and Souza, 2015) and preparedness activities in humanitarian supply chains with a focus on cyclones (Yadav and Barve, 2019). Further, Gutjahr and Nolz (2016) recommended the use of MCDM methods in the field of humanitarian aid

"Table 1"

Analytic hierarchy process (AHP) is a widely recognized MCDM to identify the importance of factors or criteria (Mardani et al., 2015). AHP was developed by Saaty in 1980. The main advantage of AHP over other MCDMs is its simple computation; however, the main limitation of the method is an inability to handle ambiguous and uncertain environments (Gumus, 2009). Thus, the AHP method is combined with fuzzy logic to improve decision-making and accurately handle any vague and uncertain environments (Kumar and Ramesh, 2019). Consequently, the study utilized a combination of the *analytic hierarchy process* (AHP) and fuzzy logic to prioritize IDT adoption barriers in organizations involved in HSCM.

Fuzzy AHP is a systematic and widely acknowledged method for solving MCDM problems (Saaty, 1988; Sharma and Sehrawat, 2020). This method employs inputs from selected experts, inheriting the ability to handle uncertain and imprecise judgments, helping to resolve MCDM problems (Khan et al., 2019; Nazam et al., 2020). The prioritization of IDTs adoption barriers in organizations involved in HSCM is an MCDM problem. It originates due to the absence of a unique optimal solution. In this instance, the decision-makers (experts) select the best alternative from a set of available alternatives (Ahn, 2017; Kabra et al., 2015).

The proposed methodology consists of three phases (see Figure 1). Initially, barriers influencing IDT adoption are identified through a systematic literature review allied with expert discussion. Secondly, the quality inputs provided by the selected experts are utilized to form pairwise comparison matrices for the barriers. Finally, the barriers are prioritized using the F-AHP method.

3.1 Fuzzy AHP

The steps for applying the F-AHP method are as follow:

Step 1: Selection of scale for pairwise comparison

Table 2 presents the scale relative importance based on triangular fuzzy numbers (TFNs), $\tilde{1}$ to $\tilde{9}$ has been used to perform a pairwise comparison between main and sub barriers. Figure 2 depicts the membership function for the corresponding TFNs.

"Figure 2"

"Table 2"

Step 2: Formation of comparison matrix

The pairwise comparison for the main barriers and sub-barriers has been conducted using TFNs (see Table 2) with the experts interested in the study. A single fuzzy comparison matrix $\check{A}$ is formed by taking the geometric mean of the pairwise comparison of all experts.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \cdots & 1 & \vdots \\ \tilde{a}_{n1} & \cdots & \cdots & 1 \end{bmatrix} \quad (1)$$

$\tilde{a}_{ij}$ is the connection of variable i with variable j. If i equal to j, then $\tilde{a}_{ij} = 1$ otherwise $1/\tilde{A}_{12}$.

Step 3: Formation of crisp comparison matrix (CCM)

The alpha cut method as proposed by Adamo (1980) has been used to convert a fuzzy CM into CCM. The method converts TFNs into a set of interval values using Equations (2) and (3). The μ index of optimism (determined by the decision-makers) is fixed as 0.5, while α is constant as 0.8.

$$\tilde{A}_{\alpha} = \begin{bmatrix} [a_{11l}^{\alpha}, a_{11u}^{\alpha}] & \cdots & \cdots & [a_{1nl}^{\alpha}, a_{1nu}^{\alpha}] \\ \vdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \vdots \\ [a_{n1l}^{\alpha}, a_{nlu}^{\alpha}] & \cdots & \cdots & [a_{nnl}^{\alpha}, a_{nnu}^{\alpha}] \end{bmatrix} \quad (2)$$

Where $\check{A}_{\alpha} = [a_L^{\alpha}, a_R^{\alpha}] = [(a_2 - a_1)\,\alpha + a_1, (a_3 - a_2)\,\alpha + a_3]$

$$\tilde{a}_{ij}^{\alpha} = \mu a_{iju}^{\alpha} + (1 - \mu) a_{iju}^{\alpha} \quad \text{where } 0 < \mu \leq 1 \quad (3)$$

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & 1 & \cdots & a_{2n} \\ \vdots & \cdots & 1 & \vdots \\ a_{n1} & \cdots & \cdots & 1 \end{bmatrix} \quad (4)$$

Step 4: Calculating the relative frequencies

The following Equation calculates the relative frequency

$$\begin{bmatrix} \frac{a_{11}}{S_1} & \frac{a_{12}}{S_1} & \cdots & \frac{a_{1n}}{S_1} \\ \vdots & 1 & \cdots & \cdots \\ \vdots & \cdots & \cdots & \vdots \\ \frac{a_{n1}}{S_n} & \frac{a_{nn}}{S_n} & \cdots & \frac{a_{nn}}{S_n} \end{bmatrix} = \begin{bmatrix} 1 & f_{12} & \cdots & f_{1n} \\ \vdots & \vdots & \cdots & \boldsymbol{a_{2n}} \\ \vdots & \vdots & \cdots & \vdots \\ f_{n1} & f_{n2} & \cdots & f_{nn} \end{bmatrix} \quad (5)$$

where $S_k = \sum_{j=1}^{n} a_{kj}$ (6)

Step 5: Calculating the entropy value

The following Equations (Equation (7)-(9)) calculates the entropy values (*Hi*) using the relative frequencies (obtained in step 4)

$$H_1 = -\sum_{j=1}^{n} (f_{ij}) log_2 (f_{1j}) \quad (7)$$

$$H_2 = -\sum_{j=1}^{n} (f_{2j}) log_2 (f_{2j}) \quad (8)$$

$$H_3 = -\sum_{j=1}^{n} (f_{nj}) log_2 (f_{nj}) \quad (9)$$

Step 6: Calculating the final weight of main and sub barriers

The resulting final weight of the main and sub barriers is obtained by the normalization of entropy values.

4. Application of F-AHP

The study utilizes the F-AHP method to examine the relative importance of barriers influencing IDT adoption in organizations involved in HSCM. The following Section discusses the problem and the finding of F-AHP.

Problem description and results

The practitioners and academicians are continuously trying to strengthen IDTs utilization in HSCM to improve humanitarian operations' performance. The utilization of IDTs is critical to responding to disasters in a timely fashion. For example, technologies were promptly deployed to deal with the disaster that occurred in Uttarakhand (a Northern state in India) during June 2013, which also indicated the need to enhance technology utilization in HSC (Livemint, 2013). Similarly, technology utilization has supported the disaster management after the Chennai floods (Sharma, 2015). There are abundant examples of humanitarian operations' efficiency and effectiveness by maximizing IDTs utilization (Jefferson and Johannes, 2016).

However, many interdisciplinary barriers hinder the effective utilization of IT, as explained in Section 2. It is impossible to select all 360-degree barriers for IDTs implementation simultaneously; it is necessary to prioritize the critical barriers step-wise. We thus adopt a multi-phase approach to address this problem.

Phase 1: Identification of barriers for IT implementation in HSCM

In this phase, 25 barriers (sub-criteria) under five main criteria (see Table 3) are identified using literature review in combination with expert discussions (comprising of technology developers, supply chain and IT experts).

"Table 3"

Phase 2: Formation of pairwise comparison matrices (PCM)

The PCM for barriers and sub barriers was formed using the scale given in Table 2. The PCM of barriers and sub- barriers is given in Tables 4-9.

"Tables 4-9"

Phase 3: Calculate the weights of barriers

The results are calculated from the pairwise comparison matrices and are placed in Table 10.

"Table 10"

5. Discussion

The present study is the first of its kind to investigate and prioritize five main barriers (strategic, organizational, technological, financial and human) and 25 sub-barriers affecting IDTs adoption in HSCM. This utilized two critical facts:

- Out of five main barriers, none of them has obtained insignificant weights. Even though there is a marginal difference in values, these are the critical barriers to IDTs adoption in HSCs.
- Strategic barriers (0.256) are the most important followed by organizational (0.218), technological (0.196), financial (0.176) and human (0.153) barriers.

The study results align with previous studies (e.g., Van Wassenhove, 2006; Kovács and Spens, 2009; Agarwal et al., 2020; Moşteanu et al., 2020). However, there is a difference in ranking of the barriers influencing the adoption of IDTs in HSCs compared to CSCs. In CSCs, human

barriers are rated ahead of other barriers in the list influencing the adoption of IDTs in HSCs. One possible reason for this may be that the organizations engaged in HSCs are motivated by the thought of saving human life and alleviating suffering in the aftermath of disasters (Gavidia, 2017). The workers employed in organizations involved in improving the performance of relief operations are well aware of the importance of their job. They understand that they are working to mitigate human suffering to save people's lives and that life is most precious compared to the time identified in CSCs. The worker understands the importance of the right kind of materials reaching the right place at the right time.

The importance of strategic barriers (SB) has been widely cited in the literature (Kabra et al., 2015). This study contributes to the relative importance of strategic sub-barriers and has found that a lack of policies for IDT adoption is a critical sub-barrier. The list of strategic barriers is in line with earlier studies that have discussed the barriers to HSCs in general. For instance, Akhtar et al., (2012) suggest that a single organization is unable to satisfy the demands of disaster-affected people. Similarly, coordination and collaboration among organizations enabled through technologies are paramount for a quick response (Agarwal et al., 2020). Nevertheless, organizations always plan their pre-disaster phases independently (Kovács and Spens, 2009). Organizations engaged in HSCs compete with each other for resources and sometimes are not able to deliver the best possible help (Bare, 2017). The absence of clear strategic policies to support the adoption of IDTs compounds the problem. This indicates that IDT adoption for HSCM is insufficient without a strategic understanding of vertical (among supply chain partners) and horizontal (between humanitarian organizations) supply chains. These findings are in line with previous studies (Van Wassenhove, 2006). Organizations lack specific knowledge about IDTs implementation in HSCs. Also, the lack of awareness about policies to support IDTs implementation is rated as a crucial strategic barrier. This is an area that needs the intervention of host governments. A change in culture, mission and vision is necessary to promote IDT adoption in organizations involved in HSCs (Kabra and Ramesh, 2015a; Maiers et al., 2005). Governments should closely monitor the process of IDTs adoption and provide necessary support such as tax rebates, subsidized power and other vital resources. Governments could also encourage commercial organizations to support IT adoption in partner organizations involved in HSCs.

Organizational barriers (OB) are fundamental to IDTs adoption. The main challenge is to develop an attractive vision for advanced IDT solutions linked with big data analytics and the

internet of things, along with supportive and efficient policies. The organizational barriers group can be mainly attributed to the short-term focus orientation compared to long term planning. The involvement of multiple organizations with diverse backgrounds produces a variety of standards for delivering humanitarian aid and that may impact the performance of HSCs (Bare, 2017). The insufficient availability of IT experts often complicates IDT adoption in humanitarian organizations. This indicates the need for robust and practical policies to recruit and retain skilled and experienced employees. The findings are in line with the previous studies (e.g., Agarwal et al., 2020; Alem et al., 2021) that have reported the need for long-term planning to improve the performance of HSCs. Moreover, Falagara Sigala et al. (2020) reported that top management support and change management are crucial for improving the performance of organizations engaged in HSCs. For example, top management can divert or allocate appropriate resources, such as time and money, to enhance the skills and capabilities of their employees through training and short-term courses. They should consider hiring more experts to introduce a digital culture and develop the mindset needed to adopt IDTs by overcoming resistance towards adoption.

Technological barriers took the third position on the scale of importance. Organizations involved in HSCs lack specific knowledge about IDTs applications and their benefits. Moreover, current technologies, such as commercial ERP packages, do not fully adhere to the needs of organizations working in the humanitarian field (Falagara Sigala et al., 2020). This lack of understanding contributes to the failure of IDTs integration into their routine operational activities. Therefore, there is a need to create awareness to motivate employees to support IDT adoption processes. Also, inadequate IT infrastructure often complicates IT implementation and its adoption (Delmonteil and Rancourt, 2017). These findings are in line with previous studies (e.g., Kabra, et. al., 2015; Maiers et al., 2015; Delmonteil and Rancourt, 2017; Baharmand et al., 2021) that stress the technological barriers in resisting the adoption of IDTs in HSC in general. Technical assistance is essential in reducing employee resistance towards changes. Practical technical training opportunities can play a key role in promoting IDT implementation for better HSCs. Humanitarian organizations can also develop in-house and more appropriate training systems to benefit their employees (Agarwal et al., 2020).

Financial barriers are in fourth place on the scale of importance. Implementing IDTs in HSCs requires financial support (Moşteanu et al., 2020). The lack of donor support is the highest contributing barrier in the financial category. The conclusions are in line with previous studies

(e.g., Agarwal et al., 2020; Kabra et al., 2017) that have cited the lack of donations as among the main challenges to HSCs. Commercial organizations should be encouraged to support the process of IDTs adoption. There is a need to streamline horizontal and vertical processes to achieve better corporate social responsibility (CSR); this can help in exploring the benefits of IDTs for HSCM. Competition for funding (Balcik et al., 2010) often complicates investment opportunities for IDT implementation. This, in turn, gives rise to a lack of funding grants for IT implementation and a lack of donor support towards IDT implementation and its adoption. The media can improve donations significantly by enhancing awareness (Aflaki and Pedraza-Martinez, 2016). Farooq et al. (2020) developed a blockchain-based system to improve transparency and security in charitable donations. Similarly, Badarudin et al. (2020) proposed a system based on blockchain for coordination between organizations to ensure swift delivery.

Finally, human barriers are rated lowest for IDTs implementation in HSCM. Lack of IT skills is ranked as the highest contributing barrier in this category. The findings agree with previous studies (e.g. Maiers et al., 2005; Kabra et al., 2017; Sahebi et al., 2020). A lack of education and training towards IDTs adoption is also a vital contributing barrier. This concludes that organizations need to develop programmes to motivate employees to utilize IT in their routine tasks. This can have a two-fold effect. First, it may contribute to the humanitarian supply chain performance. Secondly, employees can develop skills that contribute to their life-long learning. The need for transition from the traditional way of functioning into an IT-enable system must be communicated at each level of the organization. In general, the end-user's involvement in any change process is of foremost importance. Communication should be clear and concise so that no one interprets messages in the wrong way. The chances of disagreement and faulty interpretation lead to resistance in the process of IT enablement. The process of IT enablement requires a holistic IT strategy (Sakurai and Murayama, 2019).

Overall, the lack of policies to adopt technology was rated as the highest among the 25 sub-barriers. This is followed by the conflicting short-term focus goal-oriented culture, inadequate policy awareness and support from the government, lack of supply chain understanding then lack of awareness about exact technological solutions. This may be due to several reasons. First, the organization may lack relevant investment capabilities due to limited financial and technical resources (Falagara Sigala et al., 2020). Secondly, proper transparency and accountability are often absent at micro-levels to help achieve better overall supply chain performance (Burkart et al., 2016). Thirdly, humanitarian organizations are usually small in

size (Slatten et al., 2021) compared to commercial firms. Consequently, such organizations have inefficient IT structures and supply chain managers who lack IDT domain knowledge. Finally, a lack of training opportunities further complicates this problem. Training can be vital in filling the current gap in skills for IDT implementation. Training will lessen resistance to change and enhance IT enablement of the process (Kabra et al., 2017). The results are in line with the previous studies that support the need for effective leadership to transform organizations to improve the performance of HSCs (De Camargo et al., 2021; Humphries, 2013). The organizations involved in HSCs need to dedicate some budget for training to adopt IDT during the preparedness phase (Delmonteil and Rancourt, 2017). High turnover rates impact the performance of HSCs (Korff et al., 2015; Patil et al., 2021) and further complicate technology utilization (Delmonteil and Rancourt, 2017).

5.1 Theoretical Implications

The results contribute to the extant literature on HSCs by advancing our understanding of the barriers to the adoption of IDTs in organizations involved in the HSC. Although limited studies have attempted to explore the barriers to the adoption of IDTs in the organizations involved in the HSCs in the Indian context, none have considered the classification and ranking of the barriers. This calls for further investigation for more accurate results and to build a platform for future academic and professional studies. This study is the first to investigate and prioritize the barriers to implementing IDTs applications for HSCs. The identified barriers pose challenges both for practitioners and policymakers operating in humanitarian domains. From a methodological point of view, this study is an initial attempt to integrate AHP and fuzzy logic to understand the relative importance of the barriers to IDTs adoption in organizations involved in HSCs. Investigating and prioritizing the barriers to IDTs implementation extends current knowledge in HSCM. The extant literature in the context of HSC focuses on the general drivers and barriers to the HSC. Considering that the drivers and barriers to the HSC can differ from country to country, the study paves the way for future research into the challenges associated with the IDTs implementation process.

5.2 Practical Implications

The study has several managerial implications for the practitioners, policymakers and organizations involved in the domain of HSCs. The study results may help organizations involved in the HSCs to identify and evaluate the barriers to improving IDTs adoption in organizations. The findings distinguish 25 barriers to the adoption of IDTs and are grouped

into five categories as strategic, organizational, technological, financial and human barriers. Moreover, the prioritization of barriers provides a systematic way to improve the utilization of IDTs in HSCs. This enables organizations to decide which barriers they should emphasize. The findings of the study offer directions for practitioners and decision-makers to design and develop effective processes to improve the adoption of IDTs in organizations.

To reap the benefits of the IDTs, organizations need to work proactively to create more awareness about the importance of supply chain understanding in effectively managing humanitarian operations. Moreover, humanitarian organizations are further motivated to incorporate structural changes to support IDTs implementation. IDT implementation requires a cultural change in organizations to overcome resistance from employees. Commercial organizations may be encouraged to collaborate with humanitarian organizations under government rules and provisions. This can bring additional expertise to help produce more transparency in financial supply chains, motivate donors towards IDT implementation, and improve daily operations applications.

The use of IDTs should not be an act forced on employees but a process of learning and enjoyment. Organizations should organize more training workshops; they should promote success stories to improve awareness about the fitment of IDTs in solving day-to-day operational problems. Similarly, the government could run schemes to help organizations in developing more effective policies for retaining skilled employees, as the temporary nature of jobs in humanitarian organizations often complicates IDT implementation and its utilization. Policy development on retaining staff may save costs such as extra training, recruitment and talent replacement. This is particularly challenging as humanitarian environments are highly stressful. However, such policies may enhance employee trust and confidence. Furthermore, the government could collaborate with humanitarian organizations and commercial firms to run educational campaigns, online training, workshops, seminars and conferences, emphasizing IDT implementation and its benefits. This horizontal coordination between humanitarian organizations, commercial firms and governments will help tackle limited-resource issues.

6. Conclusion

The prioritization of barriers to IDT adoption in organizations involved in HSCs is a challenging and complex problem that involves several subjective criteria. MCDM techniques such as fuzzy AHP are best suited to handle such difficult problems. The study is the first of

its kind to identify and prioritize the comprehensive set of barriers to IDT adoption in HSCs, specifically in India's context. Initially, 25 sub-barriers are extracted from a literature review, duly verified by experts. The barriers are then classified into five categories viz. strategic barriers, organizational barriers, technological barriers, financial barriers and human barriers. The barriers are prioritized based on severity using fuzzy AHP. The findings indicate that strategic barriers are of greatest importance, followed by organizational, technological, financial and human barriers. The most critical barriers are lack of policies for IDT adoption; lack of awareness about government policies and support; not inviting input from end-users; short term focus rather than long-term focus on improving operations; lack of awareness about the exact technological solution; lack of supply chain understanding. The findings highlight the need for technologies specific to the context of humanitarian operations. Top management needs to come forward and communicate to the employees (end-user) the importance of technology and at the same time consider the input from end-users at the development stage of such technologies. The process of adopting IDTs involves change and change management. This necessitates the need for skill enhancement through in-depth training programs. The findings aim to assist policymakers and practitioners in developing effective strategies to improve IDT utilization in HSCM.

Similar to other studies, this study is not free from limitations. Although a three-step method adopted for this study is rigorous in terms of the way this research is conducted, it is essential to report that prioritization is based on the subjective opinions of the experts. The analysis is limited by the focus on the aspects of selected organizations. Another limitation is that the study does not establish relationships between the factors and barriers. Future research may establish or quantify the relationships between these factors. Also, contemporary humanitarian supply chains are now inundated with structured and unstructured data. Researching the benefits of advanced IDT applications such as big data analytics, the internet of things and unmanned aerial vehicles (drones) can bring interesting humanitarian practitioners' research outcomes.

References

Aflaki, A. and Pedraza-Martinez, A.J. (2016), "Humanitarian Funding in a Multi-Donor Market with Donation Uncertainty", *Production and Operations Management*, Vol. 25 No. 7, pp. 1274–1291.

Agarwal, S., Kant, R. and Shankar, R. (2020), "Evaluating solutions to overcome humanitarian supply chain management barriers: A hybrid fuzzy SWARA – Fuzzy WASPAS approach", *International Journal of Disaster Risk Reduction*, Vol. 51, p. 101838.

Agostinho, C.F. (2013), "Humanitarian Logistics: How to help even more?", *IFAC Proceedings Volumes*, Vol. 46 No. 24, pp. 206–210.

Ahn, B.S. (2017), "The analytic hierarchy process with interval preference statements", *Omega*, Vol. 67, pp. 177–185.

Akhtar, P., Khan, Z., Tarba, S. and Jayawickrama, U. (2018), "The Internet of Things, dynamic data and information processing capabilities, and operational agility", *Technological Forecasting and Social Change*, Vol. 136, pp. 307–316.

Akhtar, P., Osburg, V.-S., Kabra, G., Ullah, S., Shabbir, H. and Kumari, S. (2020), "Coordination and collaboration for humanitarian operational excellence: big data and modern information processing systems", *Production Planning & Control*, pp. 1–17.

Alamdar, F., Kalantari, M. and Rajabifard, A. (2017), "Understanding the provision of multi-agency sensor information in disaster management: A case study on the Australian state of Victoria", *International Journal of Disaster Risk Reduction*, Vol. 22, pp. 475–493.

Alem, D., Bonilla-Londono, H.F., Barbosa-Povoa, A.P., Relvas, S., Ferreira, D. and Moreno, A. (2021), "Building disaster preparedness and response capacity in humanitarian supply chains using the Social Vulnerability Index", *European Journal of Operational Research*, Vol. 292 No. 1, pp. 250–275.

Aringhieri, R., Bruni, M.E., Khodaparasti, S. and van Essen, J.T. (2017), "Emergency medical services and beyond: Addressing new challenges through a wide literature review", *Computers & Operations Research*, Vol. 78, pp. 349–368.

Badarudin, P.H.A.P., Wan, A.T. and Phon-Amnuaisuk, S. (2020), "A Blockchain-based Assistance Digital Model for First Responders and Emergency Volunteers in Disaster Response and Recovery", *2020 8th International Conference on Information and Communication Technology (ICoICT)*, presented at the 2020 8th International Conference on Information and Communication Technology (ICoICT), pp. 1–5.

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*, Emerald Publishing Limited, Vol. 41 No. 9, pp. 1522–1543.

Baharmand, H., Saeed, N., Comes, T. and Lauras, M. (2021), "Developing a framework for designing humanitarian blockchain projects", *Computers in Industry*, Vol. 131, p. 103487.

Balcik, B., Beamon, B.M., Krejci, C.C., Muramatsu, K.M. and Ramirez, M. (2010), "Coordination in humanitarian relief chains: Practices, challenges and opportunities", *International Journal of Production Economics*, Vol. 126 No. 1, pp. 22–34.

Bare, F. (2017), "Competition, Compromises, and Complicity: An Analysis of the Humanitarian Aid Sector", Claremont McKenna College, available at: https://scholarship.claremont.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=2712&context=cmc_theses (accessed 29 January 2022).

Bharadwaj, A., El Sawy, O.A., University of Southern California, Pavlou, P.A., Temple University, Venkatraman, N., and Boston University. (2013), "Digital Business Strategy: Toward a Next Generation of Insights", *MIS Quarterly*, Vol. 37 No. 2, pp. 471–482.

Buddas, H. (2014), "A bottleneck analysis in the IFRC supply chain", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Group Publishing Limited, Vol. 4 No. 2, pp. 222–244.

Burkart, C., Besiou, M. and Wakolbinger, T. (2016), "The funding—Humanitarian supply chain interface", *Surveys in Operations Research and Management Science*, Vol. 21 No. 2, pp. 31–45.

Cao, C., Liu, Y., Tang, O. and Gao, X. (2021), "A fuzzy bi-level optimization model for multi-period post-disaster relief distribution in sustainable humanitarian supply chains", *International Journal of Production Economics*, Vol. 235, p. 108081.

Cook, A. and Picucci, E. (2017), *Humanitarian Technology – Implications for Policy Research in the Asia-Pacific*, S. Rajaratnam School of International Studies, pp. 28–30.

Coppi, G. (2018), *Challenges and Opportunities for the Humanitarian Response*, International Peace Institute, pp. 28–35.

De Camargo Fiorini, P., Chiappetta Jabbour, C.J., Lopes de Sousa Jabbour, A.B. and Ramsden, G. (2021), "The human side of humanitarian supply chains: a research agenda and systematization framework", *Annals of Operations Research*, available at:https://doi.org/10.1007/s10479-021-03970-z.

Delmonteil, F.-X. and Rancourt, M.-È. (2017), "The role of satellite technologies in relief logistics", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Publishing Limited, available at:https://doi.org/10.1108/JHLSCM-07-2016-0031.

Dubey, R., Altay, N. and Blome, C. (2019), "Swift trust and commitment: The missing links for humanitarian supply chain coordination?", *Annals of Operations Research*, Vol. 283 No. 1, pp. 159–177.

Dubey, R., Bryde, D.J., Foropon, C., Graham, G., Giannakis, M. and Mishra, D.B. (2020), "Agility in humanitarian supply chain: an organizational information processing perspective and relational view", *Annals of Operations Research*, available at:https://doi.org/10.1007/s10479-020-03824-0.

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*, Taylor & Francis, Vol. 58 No. 11, pp. 3381–3398.

Dubey, R., Gunasekaran, A., Childe, S.J., Roubaud, D., Fosso Wamba, S., Giannakis, M. and Foropon, C. (2019), "Big data analytics and organizational culture as complements to swift trust and collaborative performance in the humanitarian supply chain", *International Journal of Production Economics*, Vol. 210, pp. 120–136.

El-Anwar, O., El-Rayes, K. and Elnashai, A.S. (2010), "Maximizing the sustainability of integrated housing recovery efforts", *Journal of Construction Engineering and Management*, American Society of Civil Engineers, Vol. 136 No. 7, pp. 794–802.

Falagara Sigala, I., Kettinger, W.J. and Wakolbinger, T. (2020), "Digitizing the field: designing ERP systems for Triple-A humanitarian supply chains", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Publishing Limited, Vol. 10 No. 2, pp. 231–260.

Farooq, M.S., Khan, M. and Abid, A. (2020), "A framework to make charity collection transparent and auditable using blockchain technology", *Computers & Electrical Engineering*, Vol. 83, p. 106588.

Gavidia, J.V. (2017), "A model for enterprise resource planning in emergency humanitarian logistics", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 7 No. 3, pp. 246–265.

Gumus, A.T. (2009), "Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology", *Expert Systems with Applications*, Vol. 36 No. 2, Part 2, pp. 4067–4074.

Gustavsson, L. (2003), "Humanitarian logistics: context and challenges", *Forced Migration Review*.

Gutjahr, W.J. and Nolz, P.C. (2016), "Multicriteria optimization in humanitarian aid", *European Journal of Operational Research*, Elsevier, Vol. 252 No. 2, pp. 351–366.

Hoque, R. and Sorwar, G. (2017), "Understanding factors influencing the adoption of mHealth by the elderly: An extension of the UTAUT model", *International Journal of Medical Informatics*, Vol. 101, pp. 75–84.

Humphries, V. (2013), "Improving humanitarian coordination: common challenges and lessons learned from the cluster approach", *The Journal of Humanitarian Assistance*.

Ibegbunam, I. and McGill, D. (2012), "Health commodities management system: priorities and challenges", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Group Publishing Limited, Vol. 2 No. 2, pp. 161–182.

Jefferson, T.L. and Johannes, T.W., 2016, "Using geographic information systems to support decision making in disaster response", *Intelligent Decision Technologies*, Vol. 10 No. 2, pp.193-207.

John, L., Gurumurthy, A., Soni, G and Jain, V. (2019) "Modelling the inter-relationship between factors affecting coordination in a humanitarian supply chain: a case of Chennai flood relief", *Annals of Operations Research* 283, 1227–1258.

Jung, E. and Jung, E.J. (2018), "Service-oriented architecture of environmental information systems to forecast the impacts of natural disasters in South Korea", *Journal of*

Enterprise Information Management, Emerald Publishing Limited, Vol. 32 No. 1, pp. 16–35.

Kabra, G. (2017), "Understanding barriers and enablers to training in humanitarian organizations: a SAP-LAP framework", *Development and Learning in Organizations: An International Journal*, Vol. 31 No. 6, pp. 10–13.

Kabra, G. and Ramesh, A. (2015a), "Analyzing ICT Issues in Humanitarian Supply Chain Management: A SAP-LAP Linkages Framework", *Global Journal of Flexible Systems Management*, Vol. 16 No. 2, pp. 157–171.

Kabra, G. and Ramesh, A. (2015b), "Analyzing drivers and barriers of coordination in humanitarian supply chain management under fuzzy environment", *Benchmarking: An International Journal*, Emerald Group Publishing Limited.

Kabra, G. and Ramesh, A. (2016a), "Exploring the Challenges in Implementation of Information Technology in Humanitarian Relief Organisations in India: A Qualitative Study", in Sahay, B.S., Gupta, S. and Menon, V.C. (Eds.), *Managing Humanitarian Logistics*, Springer India, New Delhi, pp. 105–113.

Kabra, G. and Ramesh, A. (2016b), "Information Technology, Mutual Trust, Flexibility, Agility, Adaptability: Understanding Their Linkages and Impact on Humanitarian Supply Chain Management Performance: Humanitarian Supply Chain Management", *Risk, Hazards & Crisis in Public Policy*, Vol. 7 No. 2, pp. 79–103.

Kabra, G., & Ramesh, A. (2017), "An analysis of the interactions among the enablers of information communication technology in humanitarian supply chain management: A fuzzy-based relationship modelling approach", in Handbook of research on intelligent techniques and modeling applications in marketing analytics (pp. 62-73). IGI Global.

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.

Kabra, G. (2017). Understanding barriers and enablers to training in humanitarian organizations: A SAP-LAP framework. *Development and Learning in Organizations: An International Journal*.

Kabra, G., Ramesh, A., Akhtar, P. and Dash, M.K. (2017), "Understanding behavioural intention to use information technology: Insights from humanitarian practitioners", *Telematics and Informatics*, Vol. 34 No. 7, pp. 1250–1261.

Kankanamge, N., Yigitcanlar, T., Goonetilleke, A. and Kamruzzaman, Md. (2020), "Determining disaster severity through social media analysis: Testing the methodology with South East Queensland Flood tweets", *International Journal of Disaster Risk Reduction*, Vol. 42, p. 101360.

Khan, A.A., Shameem, M., Kumar, R.R., Hussain, S. and Yan, X. (2019), "Fuzzy AHP based prioritization and taxonomy of software process improvement success factors in global software development", *Applied Soft Computing*, Vol. 83, p. 105648.

Korff, V.P., Balbo, N., Mills, M., Heyse, L. and Wittek, R. (2015), "The impact of humanitarian context conditions and individual characteristics on aid worker retention", *Disasters*, Vol. 39 No. 3, pp. 522–545.

Kovács, G. and Sigala, I.F. (2021), "Lessons learned from humanitarian logistics to manage supply chain disruptions", *Journal of Supply Chain Management*, Vol. 57 No. 1, pp. 41–49.

Kovács, G. and Spens, K. (2009), "Identifying challenges in humanitarian logistics", edited by Glenn Richey, R.*International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 6, pp. 506–528.

Kumar, A. and Anbanandam, R. (2019), "Location selection of multimodal freight terminal under STEEP sustainability", *Research in Transportation Business & Management*, Vol. 33, p. 100434.

Lee, H.W. and Zbinden, M. (2003), "Marrying logistics and technology for effective relief", *Forced Migration Review*.

Lewin, R., Besiou, M., Lamarche, J.-B., Cahill, S. and Guerrero-Garcia, S. (2018), "Delivering in a moving world…looking to our supply chains to meet the increasing scale, cost and complexity of humanitarian needs", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Publishing Limited, Vol. 8 No. 4, pp. 518–532.

Maiers, C., Reynolds, M. and Haselkorn, M. (2005), "Challenges to effective information and communication systems in humanitarian relief organizations", *IPCC 2005. Proceedings. International Professional Communication Conference, 2005.*, presented at the IPCC 2005. Proceedings. International Professional Communication Conference, 2005., pp. 82–91.

Mardani, A., Jusoh, A. and Zavadskas, E.K. (2015), "Fuzzy multiple criteria decision-making techniques and applications – Two decades review from 1994 to 2014", *Expert Systems with Applications*, Vol. 42 No. 8, pp. 4126–4148.

Marić, J., Galera-Zarco, C. and Opazo-Basáez, M. (2021), "The emergent role of digital technologies in the context of humanitarian supply chains: a systematic literature review", *Annals of Operations Research*, available at:https://doi.org/10.1007/s10479-021-04079-z.

Minetola, P., Iuliano, L. and Calignano, F. (2015), "A customer oriented methodology for reverse engineering software selection in the computer aided inspection scenario", *Computers in Industry*, Vol. 67, pp. 54–71.

Moşteanu, N.R., Faccia, A. and Cavaliere, L.P.L. (2020), "Disaster Management, Digitalization and Financial Resources: key factors to keep the organization ongoing", presented at the Proceedings of the 2020 4th International Conference on Cloud and Big Data Computing, pp. 118–122.

Nappi, M.M.L. and Souza, J.C. (2015), "Disaster management: hierarchical structuring criteria for selection and location of temporary shelters", *Natural Hazards*, Springer, Vol. 75 No. 3, pp. 2421–2436.

Nazam, M., Hashim, M., Baig, S.A., Abrar, M. and Shabbir, R. (2020), "Modeling the key barriers of knowledge management adoption in sustainable supply chain", *Journal of Enterprise Information Management*, Emerald Publishing Limited, Vol. 33 No. 5, pp. 1077–1109.

Negi, S. and Negi, G. (2020), "Framework to manage humanitarian logistics in disaster relief supply chain management in India", *International Journal of Emergency Services*, Vol.

ahead-of-print No. ahead-of-print, available at:https://doi.org/10.1108/IJES-02-2020-0005.

Nurmala, N., de Leeuw, S. and Dullaert, W. (2017), "Humanitarian– business partnerships in managing humanitarian logistics", *Supply Chain Management: An International Journal*, Vol. 22 No. 1, pp. 82–94.

Odedra-Straub, M. (1993), "Critical Factors Affecting Success of CBIS: Cases from Africa: Computer Science & IT Journal Article | IGI Global", *Journal of Global Information Management*, available at: https://www.igi-global.com/article/critical-factors-affecting-success-cbis/51236 (accessed 20 May 2021).

Oloruntoba, R. and Gray, R. (2006), "Humanitarian aid: an agile supply chain?", *Supply Chain Management*, Vol. 11 No. 2, p. 6.

Oloruntoba, R. and Gray, R. (2009), "Customer service in emergency relief chains", edited by Glenn Richey, R.*International Journal of Physical Distribution & Logistics Management*, Emerald Group Publishing Limited, Vol. 39 No. 6, pp. 486–505.

Oloruntoba, R. and Kovács, G. (2015), "A commentary on agility in humanitarian aid supply chains", *Supply Chain Management: An International Journal*, Emerald Group Publishing Limited, Vol. 20 No. 6, pp. 708–716.

Özdamar, L. and Ertem, M.A. (2015), "Models, solutions and enabling technologies in humanitarian logistics", *European Journal of Operational Research*, Vol. 244 No. 1, pp. 55–65.

Patil, A., Shardeo, V., Dwivedi, A., Madaan, J. and Varma, N. (2021), "Barriers to Sustainability in Humanitarian Medical Supply Chains", *Sustainable Production and Consumption*, Elsevier.

Petrudi, S.H.H., Tavana, M. and Abdi, M. (2019), "A comprehensive framework for analyzing challenges in humanitarian supply chain management: A case study of the Iranian Red Crescent Society", *International Journal of Disaster Risk Reduction*, p. 101340.

Pettit, S. and Beresford, A. (2009), "Critical success factors in the context of humanitarian aid supply chains", edited by Glenn Richey, R.*International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 6, pp. 450–468.

Queiroz, M.M., Ivanov, D., Dolgui, A. and Fosso Wamba, S. (2020), "Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review", *Annals of Operations Research*, available at:https://doi.org/10.1007/s10479-020-03685-7.

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*, Taylor & Francis, Vol. 58 No. 15, pp. 4610–4630.

Saaty, T.L. (1988), "What is the analytic hierarchy process?", *Mathematical Models for Decision Support*, Springer, pp. 109–121.

Sahebi, I.G., Masoomi, B. and Ghorbani, S. (2020), "Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain", *Technology in Society*, Vol. 63, p. 101427.

Sakurai, M. and Murayama, Y., 2019, "Information technologies and disaster management–Benefits and issues", *Progress in Disaster Science*, Vol. 2.

Sandwell, C. (2011), "A qualitative study exploring the challenges of humanitarian organisations", *Journal of Humanitarian Logistics and Supply Chain Management*, Emerald Group Publishing Limited, Vol. 1 No. 2, pp. 132–150.

Sarma, D., Das, A., Bera, U.K. and Hezam, I.M. (2019), "Redistribution for cost minimization in disaster management under uncertainty with trapezoidal neutrosophic number", *Computers in Industry*, Vol. 109, pp. 226–238.

Searle, M.S. (2020), "Is use of cyber-based technology in humanitarian operations leading to the reduction of humanitarian independence?", p. 25.

Sharma, M. and Sehrawat, R. (2020), "Quantifying SWOT analysis for cloud adoption using FAHP-DEMATEL approach: evidence from the manufacturing sector", *Journal of Enterprise Information Management*, Emerald Publishing Limited, Vol. 33 No. 5, pp. 1111–1152.

Sharma, A. (2015), "Chennai floods- a lesson in technology evolution | Digit", Digit.In, 3 December, available at: https://www.digit.in/features/science-and-technology/chennai-floods-a-lesson-on-technology-evolution-28146.html (accessed 1 February 2022).

Sinha, A., Kumar, P., Rana, N.P., Islam, R. and Dwivedi, Y.K. (2019), "Impact of internet of things (IoT) in disaster management: a task-technology fit perspective", *Annals of Operations Research*, Vol. 283 No. 1, pp. 759–794.

Slatten, L.A., Bendickson, J.S., Diamond, M. and McDowell, W.C. (2021), "Staffing of small nonprofit organizations: A model for retaining employees", *Journal of Innovation & Knowledge*, Vol. 6 No. 1, pp. 50–57.

Thomas, A. and Mizushima, M. (2005), "Logistics training: necessity or luxury?", *Fritz Institute*.

Thomas. (2003), "Enabling Disaster Response", Fritz Institute.

Tomasini, R. and Van Wassenhove, L. (2009), *Humanitarian Logistics*, Springer.

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review", *British Journal of Management*, Vol. 14 No. 3, pp. 207–222.

Van Wassenhove, L.N. (2006), "Humanitarian aid logistics: supply chain management in high gear", *Journal of the Operational Research Society*.

Venkatesh, V.G., Zhang, A., Deakins, E., Luthra, S. and Mangla, S. (2019), "A fuzzy AHP-TOPSIS approach to supply partner selection in continuous aid humanitarian supply chains", *Annals of Operations Research*, Vol. 283 No. 1, pp. 1517–1550.

Vogt, M., Hertweck, D. and Hales, K. (2011), "Strategic ICT Alignment in Uncertain Environments: An Empirical Study in Emergency Management Organizations", *2011 44th Hawaii International Conference on System Sciences*, presented at the 2011 44th Hawaii International Conference on System Sciences (HICSS 2011), IEEE, Kauai, HI, pp. 1–11.

Wakolbinger, T. and Toyasaki, F. (2014), "Impacts of Funding Systems on Humanitarian Operations", *Humanitarian Logistics: Meeting the Challenge of Preparing for and Responding to Disasters*, Kogan Page Publishers.

Yadav, D.K. and Barve, A. (2019), "Prioritization of cyclone preparedness activities in humanitarian supply chains using fuzzy analytical network process", *Natural Hazards*, Vol. 97 No. 2, pp. 683–726.

Yang, Q., Barria, J.A. and Green, T.C. (2011), "Communication Infrastructures for Distributed Control of Power Distribution Networks", *IEEE Transactions on Industrial Informatics*, presented at the IEEE Transactions on Industrial Informatics, Vol. 7 No. 2, pp. 316–327.

Yılmaz, H. and Kabak, Ö. (2020), "Prioritizing distribution centers in humanitarian logistics using type-2 fuzzy MCDM approach", *Journal of Enterprise Information Management*, Vol. ahead-of-print No. ahead-of-print, available at:https://doi.org/10.1108/JEIM-09-2019-0310.

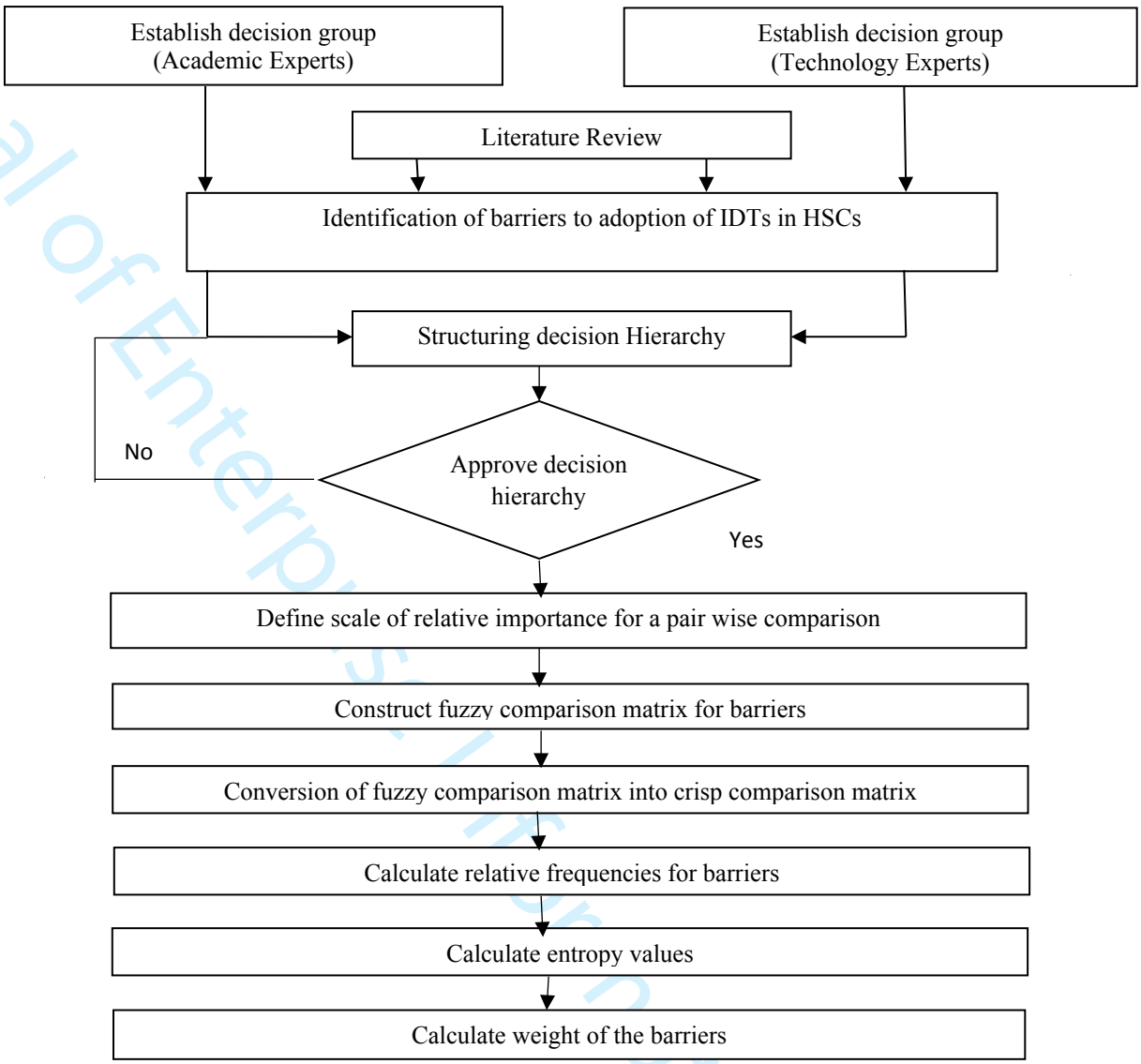

Figure 1: Research design

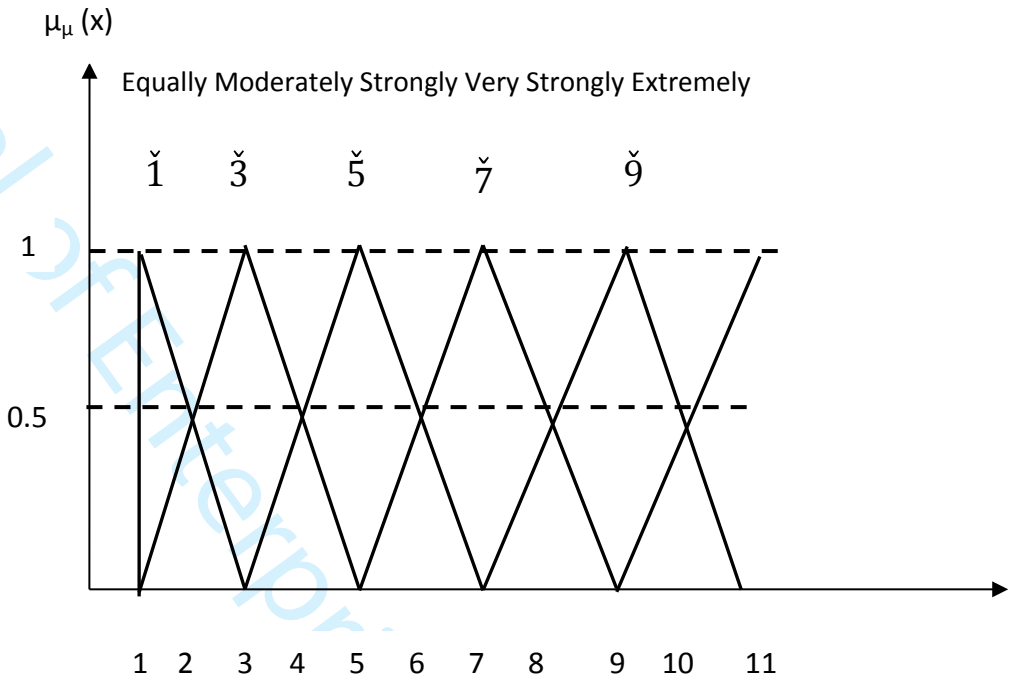

Figure 2: Fuzzy membership function for criteria

Table 1: Triangular Fuzzy Conversion Scale

Intensity of importance	Fuzzy number	Linguistic variable	Membership function	Reciprocal membership function
1	1	Equally important/preferred	(1,1,3)	(1/3,1,1)
3	3	Weakly important/preferred	(1,3,5)	(1/5,1/3,1)
5	5	Strongly more important/preferred	(3,5,7)	(1/7,1/5,1/3)
7	7	Very strongly important/preferred	(5,7,9)	(1/9,1/7,1/5)
9	9	Extremely more important/ preferred	(7,9,11)	(1/11,1/9.1/7)

Table 2: Barriers to IDTs adoption in HSCs

Main Criteria	Code	Sub Criteria
Strategic barriers (SB)	SB1	Lack of policies to adopt technology
	SB2	Inadequate policy awareness and support from Government
	SB3	Lack of management vision
	SB4	Lack of cross-organization development program
	SB5	Lack of supply chain understanding
Organizational barriers (OB)	OB1	Conflicting short-term focus goal-oriented culture
	OB2	Not inviting end-user input
	OB3	Lack of IT personnel
	OB4	Lack of pressure from other organizations
	OB5	Lack of transparency in the utilization of funds
Financial barriers (FB)	FB1	Donors support
	FB2	Lack of funds for investment in technology
	FB3	High Cost
	FB4	Competition for funding
	FB5	Fundraising expenses
Human barriers (HB)	HB1	Lack of skills to use IT
	HB2	Lack of education and training to the employees
	HB3	Lack of benchmarking about the knowledge of IT
	HB4	Workforce resistance to change
	HB5	Lack of motivation to use IT
Technological barriers (TB)	TB1	Lack of awareness about exact technological solutions
	TB2	Lack of IT enabling infrastructure
	TB3	Lack of customization
	TB4	Frequent updates of technology
	TB5	Incompatibility in IT facilities linked with different

Table 3: A pair wise comparison matrix of the major criteria

Criterion	SB	OB	FB	HB	TB
SB	(1,1,3)	(7,9,11)	(7,9,11)	(7,9,11)	(7,9,11)
OB	(1/11,1/9,1/7)	(1,1,3)	(1,3,5)	(7,9,11)	(7,9,11)
FB	(1/11,1/9,1/7)	(1/5,1/3,1)	(1,1,3)	(1,3,5)	(5,7,9)
HB	(1/11,1/9,1/7)	(1/11,1/9,1/7)	(1/5,1/3,1)	(1,1,3)	(5,7,9)
TB	(1/11,1/9.1/7)	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/9,1/7,1/5)	(1,1,3)

Table 4: A pair wise comparison matrix of the strategic barriers (SBs)

Criterion	SB1	SB2	SB3	SB4	SB5
SB1	(1,1,3)	(7,9,11)	(5,7,9)	(5,7,9)	(5,7,9)
SB2	(1/11,1/9,1/7)	(1,1,3)	(5,7,9)	(5,7,9)	(3,5,7)
SB3	(1/9,1/7,1/5)	(1/9,1/7,1/5)	(1,1,3)	(3,5,7)	(3,5,7)
SB4	(1/9,1/7,1/5)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1,1,3)	(1,3,5)
SB5	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,3)

Table 5: A pairwise comparison matrix of the organizational barriers (OBs)

Criterion	OB1	OB2	OB3	OB4	OB5
OB1	(1,1,3)	(7,9,11)	(7,9,11)	(7,9,11)	(7,9,11)
OB2	(1/11,1/9,1/7)	(1,1,3)	(5,7,9)	(5,7,9)	(5,7,9)
OB3	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1,1,3)	(3,5,7)	(3,5,7)
OB4	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1,1,3)	(3,5,7)
OB5	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1,1,3)

Table 6: A pair wise comparison matrix of the financial barriers (FBs)

Criterion	FB1	FB2	FB3	FB4	FB5
FB1	(1,1,3)	(7,9,11)	(7,9,11)	(7,9,11)	(7,9,11)
FB2	(1/11,1/9,1/7)	(1,1,3)	(3,5,7)	(3,5,7)	(3,5,7)
FB3	(1/11,1/9,1/7)	(1/7,1/5,1/3)	(1,1,3)	(7,9,11)	(7,9,11)
FB4	(1/11,1/9,1/7)	(1/7,1/5,1/3)	(1/11,1/9,1/7)	(1,1,3)	(3,5,7)
FB5	(1/11,1/9,1/7)	(1/7,1/5,1/3)	(1/11,1/9,1/7)	(1/7,1/5,1/3)	(1,1,3)

Table 7: A pair wise comparison matrix of the human barriers (HBs)

Criterion	HB1	HB2	HB3	HB4	HB5
HB1	(1,1,3)	(7,9,11)	(7,9,11)	(7,9,11)	(7,9,11)
HB2	(1/11,1/9,1/7)	(1,1,3)	(5,7,9)	(5,7,9)	(5,7,9)
HB3	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1,1,3)	(3,5,7)	(3,5,7)
HB4	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1,1,3)	(7,9,11)
HB5	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1/11,1/9,1/7)	(1,1,3)

Table 8: A pair wise comparison matrix of the technological barriers (TBs)

Criterion	TB1	TB2	TB3	TB4	TB5
TB1	(1,1,3)	(7,9,11)	(5,7,9)	(5,7,9)	(7,9,11)
TB2	(1/11,1/9,1/7)	(1,1,3)	(7,9,11)	(7,9,11)	(7,9,11)
TB3	(1/9,1/7,1/5)	(1/11,1/9,1/7)	(1,1,3)	(7,9,11)	(7,9,11)
TB4	(1/9,1/7,1/5)	(1/11,1/9,1/7)	(1/11,1/9,1/7)	(1,1,3)	(3,5,7)
TB5	(1/11,1/9,1/7)	(1/11,1/9,1/7)	(1/11,1/9,1/7)	(1/7,1/5,1/3)	(1,1,3)

Table 9: Weight of barriers for IT implementation

Major Criterion	Major Weight	Sub Criterion (Notation)	Sub Criterion Weight	Final Weight	Rank
Strategic barriers	0.2560028	SB1	0.256559445	0.06567993	1
		SB2	0.220057358	0.05633529	3
		SB3	0.180206032	0.04613324	8
		SB4	0.141332774	0.03618158	15
		SB5	0.20184439	0.05167272	5
Organizational Barriers	0.2180248	OB1	0.269423917	0.05874108	2
		OB2	0.230224759	0.0501947	6
		OB3	0.184074972	0.0401329	13
		OB4	0.116533815	0.02540726	22
		OB5	0.199742537	0.04354882	10
Finance barriers	0.1760516	FB1	0.271107957	0.047729	7
		FB2	0.233979973	0.04119255	12
		FB3	0.179264542	0.03155981	19
		FB4	0.116413684	0.02049482	24
		FB5	0.199233844	0.03507544	18
Human barriers	0.1537973	HB1	0.274285499	0.04218438	11
		HB2	0.234910947	0.03612868	16
		HB3	0.187704566	0.02886846	21
		HB4	0.106077718	0.01631447	25
		HB5	0.19702127	0.03030135	20
Technological barriers	0.1961235	TB1	0.273889081	0.05371609	4
		TB2	0.230286305	0.04516456	9
		TB3	0.181100827	0.03551813	17
		TB4	0.120710634	0.02367419	23
		TB5	0.194013154	0.03805054	14

Response Sheet

Manuscript ID "JEIM-10-2021-0456.R1" entitled "Barriers to Information and Digital Technologies Adoption in Humanitarian Supply Chain Management: A Fuzzy AHP Approach".

We are grateful to the Editor-in-chief of JEIM Prof. Zahir Irani, Associate Editor and the learned reviewers for their valuable suggestions and comments, which helped us to improve the presentation and content of the manuscript significantly. The paper has been revised to address the comment of the reviewer. A point-by-point response to the concerns raised by the learned referees follows:

Reviewer 1:

S. No.	Comment	Response to the reviewer comments
1.	Thank you for addressing the questions, however there is still need to restructure the discussion section and to clearly articulate and differentiate between the Theoretical and Practical implications resulting from this work.	The authors are thankful to the learned referee for this comment. We have revised the discussion section of the paper to clearly articulate and differentiate between the theoretical and Practical implications resulting from this work. Please refer pages 14-19 of the revised paper.
2.	There discussion section still needs to be developed further. Section 5 only has one subsection which should be avoided. Please clearly articulate and differentiate between the Theoretical and Practical implications resulting from this work. In other words, 5.0 - should be a discussion of how the findings from this work connect back with existing academic literature - then more specifically focus on the research related implications in 5.1 (Theoretical implications) and 5.2 should be the actionable implications (Practical Implications)	The authors appreciate the comments of the learned referee. As suggested, we have revised the discussion section of the paper to clearly articulate and differentiate between the Theoretical and Practical implications resulting from this work. We have restructured the discussion section. Now, Section 5.1 is Theoretical implications and Section 5.2 is Practical implications. Please refer pages 14-19 of the revised paper.

Finally, the authors provide their deep sense of gratitude to the learned referees for providing detailed constructive feedback and for improving the quality of the paper. We do hope that the revised version of manuscript will be suitable for publication in your esteem journal.

Thank you for your consideration of our work.

Best Regards