Annals of Operations Research
https://doi.org/10.1007/s10479-022-04752-x

ORIGINAL RESEARCH

Examining the barriers to operationalization of humanitarian supply chains: lessons learned from COVID-19 crisis

Vishwas Dohale[1,2] · **Priya Ambilkar**[1] · **Angappa Gunasekaran**[3] · **Vijay Bilolikar**[4]

Accepted: 29 April 2022

Abstract
Humanitarian supply chains (HSC) have vital significance in mitigating different disruptive supply chain risks caused due to natural or man-made activities such as tsunami, earthquakes, flooding, warfare, or the recent COVID-19 pandemic. Each kind of disaster poses a unique set of challenges to the operationalization of HSC. This study attempts to determine the critical barriers to the operationalization of HSC in India during the COVID-19 pandemic. Initially, we determined and validated 10 critical barriers to HSC operationalization through a Delphi method. Further, we analyzed the barriers by computing the driving and dependence power of each barrier to determine the most critical ones. To do so, we coined a distinct form of interpretive structural modeling (ISM) by amalgamating it with the neutrosophic approach, i.e. Neutrosophic ISM. The findings indicate, "lack of Government subsidies and support, lack of skilled and experienced rescuers, and lack of technology usage" are the most critical barriers that influence the streamline operations of HSC during the COVID-19 outbreak, unlike other disruptions. This is the first-of-its-kind research work that has identified and analyzed the critical barriers to HSC operationalization during COVID-19 in

Vishwas Dohale and Priya Ambilkar the first authors and have equally contributed to this work.

✉ Angappa Gunasekaran
aqg6076@psu.edu

Vishwas Dohale
Vishwas.Dohale.2017@nitie.ac.in

Priya Ambilkar
Priya.Ambilkar.2017@nitie.ac.in

Vijay Bilolikar
vijaybilolikar@gmail.com

1 Operations and Supply Chain Management (O&SCM), National Institute of Industrial Engineering, Mumbai, India

2 Decision Science and Information Systems (DSIS), Indian Institute of Management (IIM), Nagpur, Maharashtra, India

3 Penn State Harrisburg, Middletown, PA, USA

4 Fr. Conceicao Rodrigues College of Engineering, Bandra (W), Mumbai, India

Published online: 31 May 2022

the Indian context. The results and recommendations of the study can aid policymakers and HSC professionals in formulating suitable strategies for successful HSC operations.

Keywords Barriers · Humanitarian supply chain · Delphi · Neutrosophic ISM · Supply chain disruption · COVID-19

1 Introduction

The ever-changing nature of the constantly happening disruptive events posed severe challenges to humanitarian organizations to manage disaster relief supply chains (Chiappetta Jabbour et al., 2019; Dubey et al., 2019b, 2021; Dubey Gunasekaran, & Papadopoulos, 2019; Dubey, Altay, et al., 2019; Dubey, Bryde, et al., 2020; Dubey, Gunasekaran, et al., 2020; Fosso Wamba, 2020). Facilitating "the right services and goods, at the right place, in the right quantity, at the right time" in proper conditions, to the appropriate consumers with a "non-profit aim" are the critical success factors of the Humanitarian Supply Chains (HSCs) (Dubey et al., 2020; Dubey, Gunasekaran, et al., 2020; Kovács & Falagara Sigala, 2021). The typical commercial supply chain has a streamlined structure due to the availability of adequate information. However, in the case of HSCs, the necessary information regarding the requirements of survivors or alternative mediums to govern the assistance in disaster-hit regions is minimal or sometimes unavailable (Dubey et al., 2020a, 2020b, 2021; Ivanov & Dolgui, 2020).

Further, the HSCs face more challenges comparable to commercial supply chains due to inappropriate infrastructure comprising inadequate energy resources and inappropriate transport connectivity and logistics facilities, involvement of multiple stakeholders in the relief actions, such as—governmental bodies, NGOs, and the final beneficiaries (Karuppiah et al., 2021). For example, when a disaster hits any locality, different relief organizations, including Government bodies, military services, local and provincial relief organizations, non-governmental organizations (NGOs), and a few opportunistic private organizations get involved to overcome the shock of disaster with different interests, mandates, capabilities, and agendas (Balcik et al., 2010; Dubey et al., 2021; Dubey, Bryde, et al., 2020; Dubey, Gunasekaran, et al., 2020). Such complex operations are not usually seen in commercial supply chains.

Figure 1 illustrates the operationalization of HSC. The operations of HSC for minimizing human suffering in the affected regions start as soon as the humanitarian relief organizations hear the voices of people demanding relief aids. The success of HSC operations and management depends on the well-organized and synchronized HSC components, involving—relief aids, humanitarian coordinators, HSC management team, and humanitarian logistics. Each component is assigned a critical role, and all the components need to be in tandem (YU et al., 2015). Once the demand for humanitarian relief is received, the necessary relief aid, in the form of—In-kind donation, monetary donation, and/or government fundings, are collected (Besiou & Van Wassenhove, 2020; Cozzolino, 2012; YU et al., 2015). A management team of HSC is formed to govern different activities from managing public relations in collecting and supplying aids to inventory management to funds distribution to logistics management. The major role of the management team is to forecast the demand for relief aid from the affected region; decide the right quantity of resources needed (aid materials, funds, and people) and expeditiously make delivery (Dubey et al., 2021; YU et al., 2015).

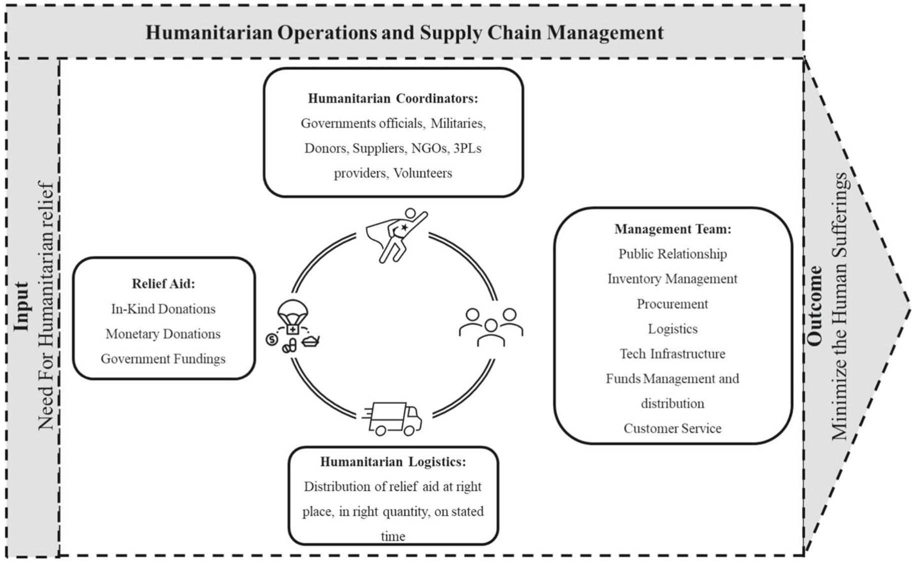

Fig. 1 Humanitarian supply chain operationalization

Another team of humanitarian coordinators, who actively participate in the field to support the disaster impacted people is formed. The role of the coordinators is to ensure the provision of aids, give moral support to affected people, help the affected people in any circumstances, and supply the aid at the quickest. The humanitarian coordinators involve—-government appointed officials, militaries, NGOs, donors, suppliers, third-party logistics (3PL) providers, and volunteers (Dubey et al., 2021; Dubey, Bryde, et al., 2020; Dubey, Gunasekaran, et al., 2020; YU et al., 2015). Finally, the relief aid distribution management through humanitarian logistics is carried out. The distribution is a critical and complex part of HSCM. The distribution of relief aid takes place through the entire system and distribution management from demand management to logistics. The last mile distribution of humanitarian aid is extremely challenging due to the unreliability of the transportation system in the disaster zone. Thus, the humanitarian coordinators play a crucial role in the logistics network of HSC to augment the effectiveness of humanitarian logistics (YU et al., 2015).

Recently, the COVID-19 pandemic has disrupted the supply chain network worldwide, resulting in substantial business and economic losses globally, and took away millions of lives (Dohale, Ambilkar, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021). As reported by World Bank, the global GDP could observe the contraction of 5.2% and stated it as the "deepest global recession in decades" (World Bank, 2020). The two waves of the COVID-19 pandemic created massive casualties. World health organization reported that as of June 21, 2021, a total of 178,837,204 confirmed cases and 3,880,450 deaths are observed (WHO, 2021). The Coronavirus pandemic has severely affected medical facilities across the globe. Countries face difficulty providing the necessary facilities, including PPE Kits, Covid testing facilities, oxygen supplies, hospital capacity, ventilators, testing kits, and vaccines. This makes COVID-19 a crucial issue for HSCs (Thompson & Anderson, 2021).

HSCs worldwide have faced unprecedented challenges during the COVID-19 pandemic. Despite having the best medical and humanitarian facilities in developed countries like the USA and Italy, the current pandemic has exposed the failure of these facilities (Dubey et al., 2021; Dubey, Bryde, et al., 2020; Dubey, Gunasekaran, et al., 2020; Thompson & Anderson, 2021). India is no objection to the devastation due to the pandemic attack. Front line workers such as—doctors, medical staff, police, military, private ambulance services, and disaster management volunteers, constantly working to mitigate the shocking havoc of COVID-19 in India. The conditions have worsened mostly during the second wave of the COVID-19 in India. As of June 21, 2021, India reported 30,028,709 confirmed cases. In India, the new high of 414,188 coronavirus infected cases was reported in a single day on May 6, 2021 (WHO, 2021). India faces shortages of medical facilities, including hospital beds, vaccines, doctors, nurses, ambulances, ventilators, communication systems, human resources, etc. To cope with these difficulties, the Government of India (GOI) encouraged Indian citizens to join hands with GOI and become COVID warriors (also termed as COVID YODDHA) to fight against COVID-19. Many NGOs, volunteers, private institutions, political parties, essential services, food and medicine supplies, etc. started participating to support GOI ("MyGOV", 2021). Certainly, the involvement of these humanitarians to fight COVID-19 situations results in the reduction of daily new cases in India and worldwide; however, the battle with the coronavirus pandemic is way long.

The management and response of HSCs in the COVID-19 pandemic is completely different and challenging compared to other disasters, viz. earthquakes, floods, etc. (Karuppiah et al., 2021). Thus, it is a crucial need of the hour to determine and analyze the difficulties and barriers in the operationalization of HSC during the COVID-19 to understand the effective tactics to resolve and smoothen the HSC operations. To this purpose, the present research work attempts to identify and analyze the critical barriers to HSC operationalization induced during the COVID-19 pandemic by addressing the following research objectives (ROs).

RO 1. To identify critical barriers to the operationalization of HSCs in India.
RO 2. To compute the contextual relationship amongst the identified HSCs barriers

The present research offers novel contributions to literature, HSC practitioners, and policymakers by reporting the critical barriers to HSC operations within the Indian context by addressing the aforementioned ROs. Initially, we identified and validated the critical barriers to HSC operationalization through a Delphi method. Further, we conceived a novel type of interpretive structural modeling (ISM) approach by combining it with the neutrosophic theory i.e., a Neutrosophic ISM to overcome the shortcomings of traditional ISM. We determined the driving and dependence power and hierarchical relationship of the identified barriers to assessing their direct and indirect effect while using the neutrosophic ISM.

The rest of the manuscript is organized as follows. The literature review on HSC management, barriers to HSCs, and HSCs during COVID-19 is provided in Sect. 2. The Delphi and proposed Neutrosophic ISM methodology adopted for conducting the research work is illustrated in Sect. 3. Section 4 discusses the findings of the study. The research implications are outlined in Sect. 5. The concluding remarks, limitations, and future research directions are provided in Sect. 6.

2 Literature review

Humanitarian supply chains are characterized as—"the relief aid flow and the information relation between the disaster-impacted population supplies recipient and the benefactor to minimize the human sorrow and burden" (Pettit & Beresford, 2005; Shivaji et al., 2016). In managing humanitarian operations, logistics and supply chains play a crucial role (de Camargo Fiorini et al., 2021; Dubey & Gunasekaran, 2016; Ozdemir et al., 2021).

Humanitarian supply chain management (HSCM) is defined as—"The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption to alleviate the suffering of vulnerable people" (Behl & Dutta, 2019). Building and managing resiliency is the core strategy of HSCM to fight the disaster and provide the relief-aid (Agarwal et al., 2019; Cozzolino, 2012), unlike the commercial supply chains.

HSCs operate under extremely unpredictable and uncertain conditions than the commercial supply chains (Wassenhove, 2006; YU et al., 2015). The forecasting in HSC is extremely difficult due to the magnitude of destruction and the unpredictability of disruption. Thus, the management of the humanitarian supply chain network is incredibly challenging. The unique characteristics of HSC require a high level of agility, flexibility, and effectiveness (Fosso Wamba, 2020; Holguín-Veras et al., 2013). Since minimizing human suffering and saving lives are the highest priorities during the disaster, the objectives of HSC differ drastically from the commercial supply chains. For example, the objectives considered in commercial supply chains are related to cost minimization and profit maximization. On the other hand, HSC considers minimizing social costs comprising supply chain cost and deprivation cost as the prime objective (Holguín-Veras et al., 2013).

The United Nations (UN) has pointed out the *essêncià* of the humanitarian facet in the HSCs for mitigating the post-disaster risks and streamlining the relief operations (Behl & Dutta, 2019). The UN reported that a total of 235 million people would require humanitarian assistance and protection in 2021, which is nearly 40% more than 2020 and almost entirely from the COVID-19 impact (United Nations, 2021). Therefore, the UN outlined an action plan entitled—'Global Humanitarian Response Plan COVID-19' to facilitate the exercise of an impactful response to the COVID-19 pandemic through humanitarian aid (United Nations, 2020). Hence, HSCs are critical when a disaster situation strikes societies. Thus, HSCs and their operations management have received enormous attention in the body of knowledge (Chiappetta Jabbour et al., 2019; Fosso Wamba, 2020). In the recent COVID-19 pandemic, the role of HSCs is irrefutable. However, the COVID-19 pandemic exposed severe flaws in the commercial and humanitarian supply chains to respond to the unique set of challenges posed due to the current pandemic (Thompson & Anderson, 2021). In this section, we extensively reviewed the extant literature to enlist the studies on 'HSCM during COVID-19 outbreak' theme and identify critical barriers in the humanitarian supply chain operations. The barriers are discussed next.

2.1 Barriers to the operationalization of HSCs

Disasters often disrupt the functioning of societies and localities and create an adverse impact on livelihood. However, effectively and efficiently managed humanitarian relief operations aids in alleviating the casualties and damages (Malmir & Zobel, 2021). The barriers are the critical challenges that disturb the operations of the system. The barriers to humanitarian supply chains are—the hurdles within the humanitarian relief operations that impact the smooth flow of the essential supplies from the benefactors to the beneficiaries. Recently, the entire world is witnessing an unparalleled disaster owing to the COVID-19 pandemic. The nature of the coronavirus is not well understood yet, resulting in contradictory or inadequate information transmitted to the masses, resulting in confusion amongst the responders and the citizenry (Thompson & Anderson, 2021). These challenges altogether make the relief operations slow, resulting in prolonged medical service and causalities (Malmir & Zobel, 2021; Thompson & Anderson, 2021).

As the nature of disasters and their induced risk to supply chains is different, the nature of barriers posed by the different disasters can be different (Cozzolino, 2012; Dohale et al., 2021; Dohale, Ambilkar, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021; Dohale, Verma, et al., 2021). Pandemics are the unique kind of disasters that creates a negative impact on a massive multi-country or worldwide scale, which may or may not be observed during natural disaster (Dora & Kumar, 2020; Thompson & Anderson, 2021). Although the set of barriers to HSC operations may be similar, but their nature and impact variers as per the type of disaster. The COVID-19 pandemic has induced an unprecedented set of barriers to HSC operationalization. The unanticipated COVID-19 pandemic crisis intensified the stress on a humanitarian system struggling to cope with existing challenges in a distinct nature (Development Initiatives, 2021). Through an extensive literature review, we identified a set of 14 different barriers. The details of the 14 barriers to the operationalization of HSC are provided in "Appendix".

2.2 Summary of existing studies on HSCM and COVID-19

As discussed earlier, HSCM has received enormous interest from researchers, policymakers, and practitioners, resulting in a significant body of literature (Behl & Dutta, 2019; Chiappetta Jabbour et al., 2019; Fosso Wamba, 2020). In recent, researchers across the globe made an effort to contribute the relevant studies on the 'HSCM during the COVID-19 times' theme. Many reputed outlets provide a special issue on this theme to encourage researchers to rethink HSCM through the "pandemic-crisis" lens. We critically reviewed the literature to identify such studies and enlisted them to highlight their contribution and the methodology adopted. The studies on 'HSCM during the COVID-19 times' theme are summarized in Table 1.

2.3 Research agenda

As evident from the literature review, HSCs have significant importance in disaster management activities. Although authors tried to discuss and resolve different issues in HSCs during COVID-19, there is a critical need to develop a foundationary work to analyze the challenges to the successful operationalization of HSCs during the pandemic outbreak. Some prominent research gaps (RGs) have emerged through the review of extant literature. Firstly, the literature has reported the essence of HSCs during COVID-19 (Thompson & Anderson, 2021); however, the literature is deficient in determining the critical barriers that affect the streamlined operationalization of the HSCs. Further, as evident from Table 1 and to the best of author's knowledge, the literature is at the nascent stage to demonstrate the suitable strategies to overcome the barriers to HSCs operations during the COVID-19 pandemic outbreak. The aforementioned gaps posed a critical need to identify and define barriers to the operationalization of HSCs during COVID-19 in developing countries like India and evaluate the interrelation between the barriers and determine strategies to mitigate them. The research gaps lay a foundation for the following research questions (RQs).

RQ 1. What are the critical barriers influencing the HSC operations during the COVID-19 pandemic in India?
RQ 2. What is the contextual relationship amongst the HSC operationalization barriers?
RQ 3. What are the mitigating strategies to overcome the HSC operationalization barriers?

Table 1 Summary of HSCM studies during COVID-19

Authors	Contribution	Methodology
Kovács and Falagara Sigala (2021)	Provides an overview of the key takeaways from HSC practices to mitigate the disruptions in the supply chain of other sectors	Qualitative—Conceptual
Malmir and Zobel (2021)	Developed HSC planning model to optimize the entire HSC cost comprising delivery costs and pandemic relief cost	Simulation-based nonlinear mathematical modeling
de Camargo Fiorini et al. (2021)	Investigated the state-of-the-art research focusing on the "human aspect" of HSC and its essence in disaster management	Systematic Literature Review
Thompson and Anderson (2021)	Provides the future research agenda for understanding and making the HSC resilient through the viewpoint	Conceptual Viewpoint
García Castillo (2021)	Developed a mathematical model to decide the appropriate cash-based and in-kind distributions in the humanitarian emergencies	Quadratic mixed-integer mathematical model
Allahi et al. (2021)	Evaluated the best option to improve refugees' health and education during COVID-19	System Dynamics Simulation
Friday et al. (2021)	Reviewed the extensive literature on optimizing the stock levels and boosting resilience in HSCs context to determine the knowledge gaps and provide future research opportunities	Systematic Literature Review
Karuppiah et al. (2021)	Identified the critical strategies to manage the sustainable humanitarian supply chain management during the COVID-19 pandemic	Analytic Hierarchy Process

3 Research methodology

The proposed methodology deployed in this research work comprises three stages to analyze the barriers to the operationalization of HSCs in India. The first stage comprises identifying and validating the barriers through the Delphi method. In the second stage, we utilized the ISM method to develop the hierarchical model of the barriers, which helps determine the contextual interrelationship between the verified barriers. Finally, in the third stage, the ISM is combined with the neutrosophic approach, i.e. Neutrosophic ISM, to retain the individual responses from the industry experts. Further, the neutrosophic responses are amalgamated to compute the driving and dependence power of the barriers for determining the critical barriers to HSCs operationalization. The detailed methodical roadmap for conducting the present research is shown in Fig. 2.

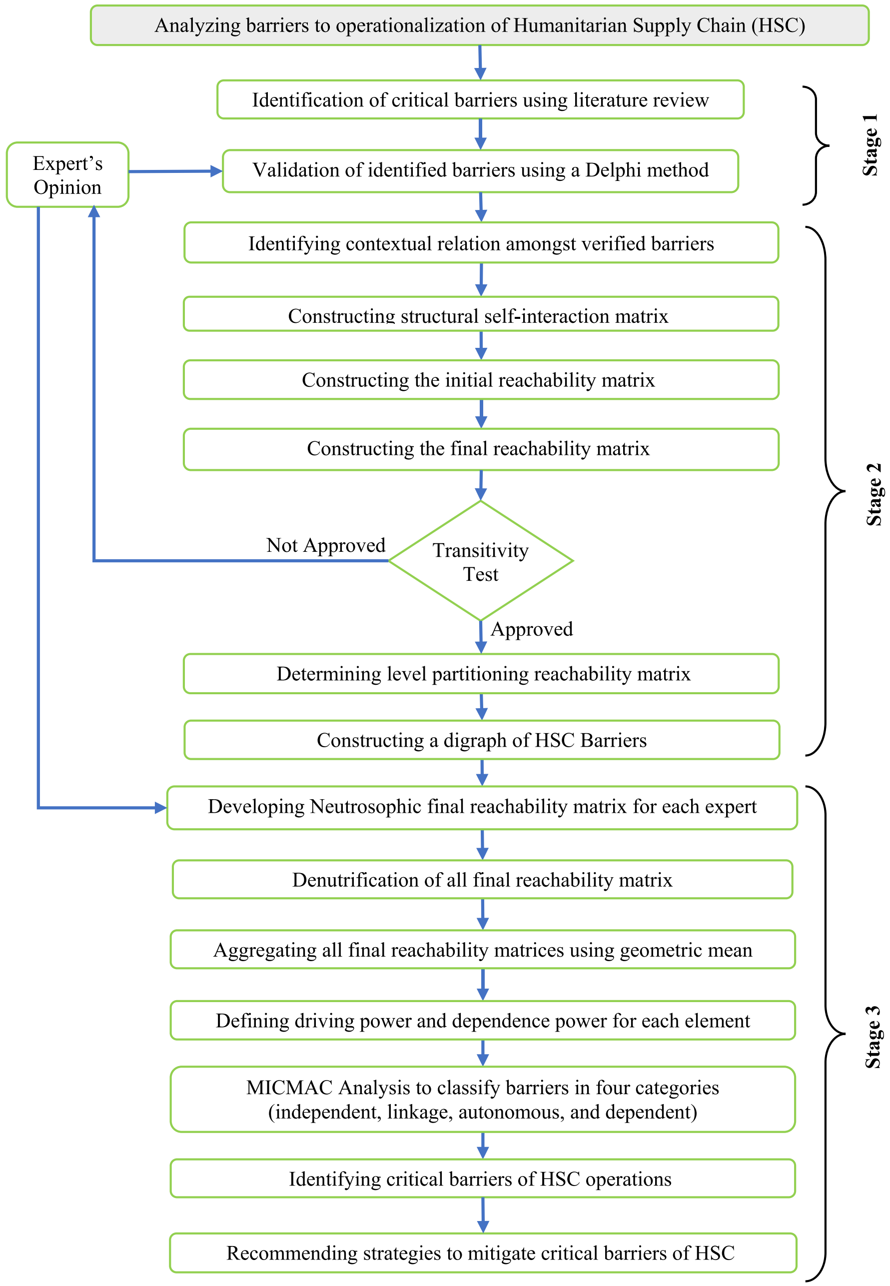

Fig. 2 Research methodology

3.1 Delphi

Initially, we conducted a comprehensive literature review to identify the critical barriers that obstruct the smooth flow of the supplies to survivors through HSC operations. Through a thorough literature review, we identified a total of 14 barriers, as discussed in Sect. 2.2 (refer "Appendix"). The identified barriers are validated to determine their relevance in the study context, i.e. barriers induced during COVID-19 in the Indian context. We utilized a Delphi method to validate the barriers.

Delphi is an iterative method that aids the processing of the experts' opinions on the studied phenomenon recursively until the arrival of the consensus amongst experts' opinions (Delbecq et al., 1975; Dohale et al., 2019; Dohale, Ambilkar, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021; Emovon et al., 2018). Delphi comprises continuous brainstorming to collect the data on validation of the topic under investigation (Moktadir et al., 2019). The rationale for utilizing Delphi in this research are—(1) Delphi is a widely deployed technique for identification and validation of the aspects viz. barriers, criteria, performance measures, enablers, etc. using experts' opinions (Emovon et al., 2018; Kumar et al., 2021); (2) Delphi utilizes organized procedure to gather experts opinions and conducts anonymous assessments of the responses (Linstone & Turoff, 2002); (3) Each expert equally collaborates in Delphi; thus the issues concerning influential personalities, conflict of opinions, and group pressures can be eliminated resulting in more accurate judgments (Dohale et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021; Gulati et al., 2018); (4) Delphi can consider the experts from a wide geographical area (Linstone & Turoff, 2002).

Selecting appropriate experts is crucial in the Delphi procedure (Devaney & Henchion, 2018; Dohale, Ambilkar, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021). We assessed the experts based on the three criteria—(1) knowledge and experience of the topic of investigation (minimum five years of experience); (2) current working position within the organization; and (3) availability and interest to participate in the study (Bokrantz et al., 2017). Delphi requires a sample of 5 to 20 experts to conduct a validation procedure (Balasubramanian & Agarwal, 2012; Dohale et al., 2019, 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021; Emovon et al., 2018). Thus, we deployed 6 experts from NGOs, Academics (HSCM), and the 'Relief and Rehabilitation Department (GOI)' involved in the humanitarian logistics during COVID-19 and following the above-mentioned expert selection criteria to validate the identified barriers using a Delphi method. The detailed profile of the six experts is provided in Table 2.

Delphi involves different consensus measurement techniques such as—interquartile range (IR), average percent of majority opinions (APMO) cut-off rate, subjective analysis, etc. (Gracht, 2012). We utilized a content validity ratio (CVR) technique devised by Lawshe (1975) to measure the consensus due to its additive advantage over other consensus measurement techniques, such as—(1) usage of a balanced three-point scale (essential, useful but not essential, and not necessary) for measurement (Ayre & Scally, 2014); (2) extensively focused, user-friendly and transparent; (3) consist critical threshold value for reference; (4) applicability of CVR is re-examined (Surip et al., 2019; Wilson et al., 2012). Further, the CVR aids experts within the domain of study to evaluate and determine the validity of the criteria (Rutherford-Hemming, 2018). The CVR is expressed as:

$$CVR = \frac{N_{PE} - \left(\frac{N}{2}\right)}{\frac{N}{2}} \tag{1}$$

Table 2 Profile of the experts

Expert	Background	Designation	Educational qualification	Experience (years)
Expert-1	Government	District Consultant, Relief and Rehabilitation Department, Govt. of Maharashtra, India	Post-graduate	31 +
Expert-2	NGO	Senior Consultant, Supply & Logistics	Post-graduate	19 +
Expert-3	NGO	Manager, Operations and Fund Raising	Post-graduate	16 +
Expert-4	NGO	Senior Manager, Finance and Operations	Post-graduate	14 +
Expert-5	NGO	Deputy Manager, Supply & Logistics	Ph.D	22 +
Expert-6	Academia	Professor, Humanitarian Supply Chain and Logistics	Ph.D	29 +

where CVR—consistency validity ratio; N_{PE}—number of experts suggesting the barriers is essential; N—total number of expert.

The threshold value of CVR is set at 0.29 (Dohale et al., 2019; Emovon et al., 2018; Lawshe, 1975). We computed the CVR values of each identified barrier and enlisted in Table 3. Barriers with a CVR score $\geq$ 0.29 are retained for the study, while the other barriers are rejected. Thus, employing CVR-based Delphi, we obtained the 10 crucial barriers to the HSC operationalization during COVID-19 in India.[1] The barriers are—Lack of information sharing (HSCB 1), Lack of supply chain visibility (HSCB 2), Lack of collaboration (HSCB 3), Lack of Agility (HSCB 4), Lack of Govt. subsidies and support (HSCB 5), Lack of technology usage (HSCB 6), Lack of coordination amongst HSC actors (HSCB 7), Lack of awareness to end-consumer (HSCB 8), Lack of skilled and experienced rescuers (HSCB 9), Weak monitoring of HSC (HSCB 10). These validated and retained barriers are further analyzed using Neutrosophic ISM.

3.2 Neutrosophic interpretive structural modeling

Interpretive Structural Modeling (ISM) was conceived by Warfield (1974) to create a structural model of the system under study to simplify it (Sushil, 2020). ISM helps to determine the direct and indirect relationships between the factors affecting the system under consideration. ISM utilizes expert opinions for identifying the contextual inter-relationship between the various factors influencing the system. ISM has additive advantages over the analytical hierarchy process and analytical network process in capturing 'what' and 'how' phenomenon. ISM also provides insights about the "leads to" relationship between factors in real-life problems. However, ISM comprises several major shortcomings, such as—(1) It uses a binary

[1] Retained barriers and their respective CVR values are given in Table A1 in Supplementary File.

Table 3 Comparison of different forms of ISM

Type of ISM	Benefits	Drawbacks
Classical ISM	Identify the relationships between different criteria	Uses binary scale to measure the influence
	Determine the influences of criteria over each other	Fails to compute the level of influence (such as low, medium, high, etc.)
	Portrays an intricate system in a simplified way	Fails to handle imprecise and vague information usually exists in real cases
	Identifies the structure of the influential aspects in a system typically in a hierarchical way, i.e. digraph	Cannot answer "why" aspects which typically helps in a theory building
	Evaluate the driving and dependence power of aspects	Used a Consensus vote method to aggregate the experts' judgments, which itself comprises drawbacks (Huang et al., 2021; Jena et al., 2017; Sindhwani & Malhotra, 2017; Sushil, 2012)
	Explain "what" and "how" characteristics of a system (Kamble et al., 2018; Li et al., 2019; Majumdar & Sinha, 2019; Sivaprakasam et al., 2015)	
Total ISM (TISM)	Includes all the benefits of ISM	Uses binary scale to measure the influence
	Attempts to answer the "why" phenomenon (Huang et al., 2021; Jena et al., 2017; Sindhwani & Malhotra, 2017; Sushil, 2018)	Fails to compute the level of influence
		Fails to handle imprecise and vague information usually exists in real cases
		Uses consensus vote method to aggregate the experts' judgments (Huang et al., 2021; Jena et al., 2017)
Fuzzy ISM	Includes all the benefits of classical ISM	We have identified the following drawbacks in Fuzzy ISM
	Effectively Handles the imprecise or vague nature through one-grade membership degree	Aggregates the experts' opinions using the consensus vote method

Table 3 (continued)

Type of ISM	Benefits	Drawbacks
	Describe the preference judgment values of the decision-maker efficiently	Unable to incorporate the membership degrees, namely—'truth, indeterminacy, and falsity' degrees
	Computes the level of influence (Lamba & Singh, 2018; Sindhwani et al., 2018; Srivastava & Dashora, 2021; Tseng et al., 2019)	Difficult to compute transitivity
Neutrosophic ISM (N-ISM)	Comprises all the benefits of ISM, TISM, Fuzzy ISM	The computation time required for calculating driving and dependence power is comparatively more than other forms of ISM
	Describes the preference of the decision-maker efficiently	
	Handles vagueness and uncertainty effectively than other ISMs, due to consideration of three different grades "truth, indeterminacy, and falsity degree"	
	Point out how to improve inconsistent judgments	
	Utilized a widely used and mathematically sound geometric mean approach to aggregate the opinions of multiple experts	
	Due to the use of neutrosophic theory and the geometric mean method, N-ISM is more mathematically validated and justifiable than the other ISM forms	

scale to measure the influence of one criterion over the other (1—Influence, 0—No Influence); as a result, there is often a vagueness and subjectivity in the judgment. (2) It fails to answer 'why' phenomenon (3) It purely relies on the consensus vote method, in which the accuracy in judgment may be impacted due to influential personalities or the senior-level expert, group pressure, etc. Due to these reasons, the other forms of ISM, such as TISM and Fuzzy ISM are coined. However, in every form, some drawbacks are still observed (refer Table 3).

In this research work, we developed a novel form of ISM by combining it with the neutrosophic approach, i.e. Neutrosophic ISM. A detailed comparison of all the forms of ISM is enlisted in Table 3. The rationale for selecting the neutrosophic approach is its ability to deal with the uncertainties and inconsistencies in decision-making (Nabeeh et al., 2019). It effectively handles indeterminant cases, unlike fuzzy sets (Nabeeh et al., 2021). Neutrosophic approach effectively computes indeterminacy within decision-makers' perceptions (Abdel-Baset et al., 2019). Different neutrosophic MCDM methods are already reported in the literature, including neutrosophic AHP (Abdel-Basset et al., 2017), neutrosophic DEMATEL, and neutrosophic ANP (Nabeeh et al., 2021). Neutrosophic approach aids in avoiding unclear, vague, and inexact judgments of experts (Abdel-Baset et al., 2019). Thus, we coupled both approaches, ISM and neutrosophic, to utilize it in a robust way to overcome the limitation of ISM and its other types.

3.3 Definitions of neutrosophic sets

The strength of neutrosophic sets lies in their ability to handle inconsistent and vague data by studying the level of truth, indeterminate, and false degrees of the data (Broumi et al., 2020; Nabeeh et al., 2019). Literature has provided the critical definitions of neutrosophic sets, single-valued neutrosophic number, triangular neutrosophic number, and trapezoidal neutrosophic number (Abdel-Basset et al., 2018; Broumi et al., 2020; Pamucar et al., 2020). The definitions are discussed next.

Definition 1 (*Neutrosophic set*) Let X be a space of points, $x \in X$. The neutrosophic set P characterized by three membership functions which are a truth-membership function $T_P(x)$, an indeterminacy-membership function $I_P(x)$, and falsity-membership function $F_P(x)$. Where, $T_P(x)$, $I_P(x)$ and $F_P(x)$ are real standard or real non-standard subsets of$]-0, 1+$ $[$. That is for $T_P(x)$, $I_P(x)$ and $F_P(x)$: $X \rightarrow]^{-}0, 1^{+}[$. Also, the sum operator of $T_P(x)$, $I_P(x)$ and $F_P(x)$ has no restrictions. Therefore, $0- \leq supT_P(x) + supI_P(x) + supF_P(x) \leq 3^{+}$.

Definition 2 (*Single valued neutrosophic number (SVN)*) Let X be a universe of discourse. A single-valued neutrosophic (SVN) set P over X is an object taking the form as $X = \{x, T_P(x), I_P(x), F_P(x) : x \in X\}$, where $T_P(x)$, $I_P(x)$, and $F_P(x)$: $X \rightarrow [0, 1]$ with $0 \leq T_P(x) + I_P(x) + F_P(x) \leq 3 forall x \in X$. For convenience, the SVN number is typified by $P = (p, q, r)$, where $p, q, r \in [0, 1]$ and $p + q + r \leq 3$.

Definition 3 (*Single valued triangular neutrosophic number (SVTN)*) Suppose $\alpha_{\tilde{p}}, \theta_{\tilde{p}}, \beta_{\tilde{p}} \in [0, 1]$ and $p_1, p_2, p_3 \in M$ where $p_1 \leq p_2 \leq p_3$. Then, a triangular neutrosophic (SVTN) number, $\tilde{p} = (p_1, p_2, p_3); \alpha_{\tilde{p}}, \theta_{\tilde{p}}, \beta_{\tilde{p}}$ is a neutrosophic set on the real line set M. The truth-membership, indeterminacy-membership, and falsity-membership functions of the SVTN number are defined as:

$$T_{\tilde{p}}(x) = \begin{cases} \alpha_{\tilde{p}} \frac{(x-p_1)}{(p_2-p_1)} & (p_1 \leq x \leq p_2) \\ \alpha_{\tilde{p}} & (x = p_2) \\ 0 & otherwise, \end{cases} \tag{2}$$

$$I_{\tilde{p}}(x) = \begin{cases} \frac{((p_2-x)+\theta_{\tilde{p}}(x-p_1))}{(p_2-p_1)} & (p_1 \leq x \leq p_2) \\ \theta_{\tilde{p}} & (x = p_2) \\ 1 & otherwise, \end{cases} \tag{3}$$

$$F_{\tilde{p}}(x) = \begin{cases} \frac{((p_2-x)+\beta_{\tilde{p}}(x-p_1))}{(p_2-p_1)} & (p_1 \leq x \leq p_2) \\ \beta_{\tilde{p}} & (x = p_2) \\ \frac{((x-p_2)+\beta_{\tilde{p}}(p_3-x))}{(p_3-p_2)} & (p_2 \leq x \leq p_3) \end{cases} \tag{4}$$

where $\alpha_{\tilde{p}}, \theta_{\tilde{p}}$ and $\beta_{\tilde{p}}$ represents the maximum degree of truth-membership, the minimum degree of indeterminacy-membership, and the minimum falsity-memberships degree, respectively. SVTN number $\tilde{p} = (p_1, p_2, p_3); \alpha_{\tilde{p}}, \theta_{\tilde{p}}, \beta_{\tilde{p}}$ may express an ill-defined quantity of the range, which is approximately equal to the interval $[p_2, p_3]$.

Definition 4 (*Single valued trapezoidal neutrosophic number (SVTrNN)*) A single-valued trapezoidal neutrosophic number (SVTrNN) is represented as $\tilde{p} = (p_1, p_2, p_3, p_4), (q_1, q_2, q_3, q_4), (r_1, r_2, r_3, r_4)$. The SVTrNN parameters satisfy the following condition: $(p_1 \leq p_2 \leq p_3 \leq p_4), (q_1 \leq q_2 \leq q_3 \leq q_4), (r_1 \leq r_2 \leq r_3 \leq r_4)$ (Pamucar et al., 2020). Then, the truth $\left(T_{\tilde{p}}(x)\right)$, indeterminacy $(I_{\tilde{p}}(x))$, and falsity $(F_{\tilde{p}}(x))$ membership degrees can be represented in following manner.

$$T_{\tilde{p}}(x) = \begin{cases} \frac{(x-p_1)}{(p_2-p_1)}, & (p_1 \leq x \leq p_2) \\ 1, & (p_2 \leq x \leq p_3) \\ \frac{(p_4-x)}{(p_4-p_3)}, & (p_3 \leq x \leq p_4) \\ 0, & Otherwise \end{cases} \tag{5}$$

$$I_{\tilde{p}}(x) = \begin{cases} \frac{(x-q_1)}{(q_2-q_1)}, & (q_1 \leq x \leq q_2) \\ 1, & (q_2 \leq x \leq q_3) \\ \frac{(q_4-x)}{(q_4-q_3)}, & (q_3 \leq x \leq q_4) \\ 0, & Otherwise \end{cases} \tag{6}$$

$$F_{\tilde{p}}(x) = \begin{cases} \frac{(x-r_1)}{(r_2-r_1)}, & (r_1 \leq x \leq r_2) \\ 1, & (r_2 \leq x \leq r_3) \\ \frac{(r_4-x)}{(r_4-r_3)}, & (r_3 \leq x \leq r_4) \\ 0, & Otherwise \end{cases} \tag{7}$$

In the present research work, we adopted trapezoidal neutrosophic number due to their advantages over other. The advantages of SVTrNN are discussed next.

3.4 Advantages of SVTrNN

The advantages of SVTrNN over other neutrosophic numbers provided by Broumi et al. (2020) and Pamucar et al. (2020) includes:

- The SVTrNN is a generalized form of a single and triangular neutrosophic number.
- The SVTrNN is distributed widely over any scale, making it arithmetically suitable to express the judgments.
- The SVTrNN is illustrated in an interval form of three independent membership degrees.
- The SVTrNN can effectively express neutrosophic information than the single and triangular neutrosophic.

Therefore, the SVTrNN is more suitable for computing neutrosophic multiple attribute decision-making problems (Broumi et al., 2020).

3.5 Neutrosophic ISM procedure

In this section, the main steps for the computation of the 'driving and dependence power' of barriers using the neutrosophic ISM framework are presented with a detailed description.

3.5.1 Step 1: Develop a structural self interaction matrix

Develop a pairwise comparison matrix, i.e. a structural self-interaction matrix (SSIM) based on the contextual relationship amongst the 10 HSC operationalization barriers using experts' opinions. The relationship between factors can be expressed in terms of four symbols as follows-

V: depicts attribute i aids in achieving attribute j;
A: depicts attribute j aids in achieving attribute i;
X: depicts attributes i and j aids in achieving each other; and.
O: depicts no relationship amongst attributes i and j.

The number of experts required for developing SSIM and conducting ISM ranges between 5 and 15 experts to maintain adequate and precise results (Sonar et al., 2020). Thus, in this research work, we contacted the same six experts who performed Delphi for conducting all the steps of neutrosophic ISM to have a uniqueness and biasfree results. All the responses related to SSIM from the six experts are gathered and correlated. The final SSIM is developed based on the highest frequency assigned to V, A, X, and O (Chirra & Kumar, 2018). For example—in any pairwise comparison between barrier i and barrier j, the responses from six experts received as—3 experts provided V, 2 experts provided A, 1 expert provided X, and no experts with O, in this condition being V has the highest frequency, it is considered in the final SSIM. In the case of the same frequency got assigned to V, A, X, or O, then that comparison is reinitiated until a clear high-frequency-based judgment is received (Chirra & Kumar, 2018). After conducting this iterative process, a final SSIM is prepared, as shown in Table 4.

Table 4 Structural self interaction matrix (SSIM)

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1	V	O	V	O	A	V	V	O	X
HSCB2		1	V	X	O	A	V	V	O	X
HSCB3			1	O	A	O	X	O	O	O
HSCB4				1	O	A	A	O	O	A
HSCB5					1	V	O	V	V	V
HSCB6						1	V	V	A	V
HSCB7							1	O	O	V
HSCB8								1	O	O
HSCB9									1	V
HSCB10										1

3.5.2 Step 2: Develop an initial reachability matrix

The values 1 and 0 are substituted in the SSIM by replacing V, A, X, and O to get the initial reachability matrix, as shown in Table 5. To replace V, A, X, and O by values 1 and 0, the following rules are considered (Li et al., 2019; Sonar et al., 2020; Warfield, 1974).

- If in the SSIM the relation of (i, j) is defined using V, then the (i, j) is replaced by 1, while the (j, i) is replaced by 0.
- If in the SSIM the relation of (i, j) is defined using A, then the (i, j) is replaced by 0, and the (j, i) is replaced by 1.
- If in the SSIM the relation of (i, j) is defined using X, then the (i, j) and the (j, i) are replaced by 1.
- If in the SSIM the relation of (i, j) is defined using O, then the (i, j) and (j, i) are replaced by 0.

3.5.3 Step 3: Develop a final reachability matrix

In this step, a final reachability matrix is developed by using a transitivity check. Transitivity includes a theory of sets comprising Boolean multiplication and addition (Kumar et al., 2021). It aids in managing the consistency within the matrix (Majumdar et al., 2021; Ruiz-Benítez et al., 2018; Singh et al., 2007). According to the transitivity concept: if entity "i" is related to entity "j", and entity "j" is related entity "k," then entity "i" must be related to entity "k" (Raut et al., 2019; Singh et al., 2007; Toktaş-Palut et al., 2014). The final reachability matrix is developed using the transitivity concept, as shown in Table 6.

3.5.4 Step 4: Level partitioning

The final reachability matrix is used to determine the reachability sets and antecedent sets for each barrier considered in this study. The reachability set of a barrier comprises other barriers present in the row, including the barrier itself and having value '1'. Whereas the antecedent set for a barrier comprises any barriers having value '1' and present in the column, including the barrier itself. Further, the interaction set is determined for all barriers. Any barriers having the same reachability and intersection sets are placed on the top level in the ISM digraph. The barriers retaining the top position are separated from the list, and the same procedure is repeated to determine the position of the other barriers. Table 7 provides the details about the reachability, antecedent, and interaction sets for all the barriers.

3.5.5 Step 5: Constructing a diagraph

A digraph is a model in hierarchical form constructed through the level partitioning of the final reachability matrix. As explained earlier, the barrier retaining the top position is placed at the top of the digraph. Further, the barriers retaining the second position are placed in the next levels. The process is repeated until all barriers are positioned in a digraph. Figure 3 represents the digraph constructed in the present study.

3.5.6 Step 6: Determining the driving and dependence power of the barriers

In ISM, the relationship amongst two attributes is represented by: 0 for no influence and 1 for influence. However, in real-life situations, the influence can be represented as—absolutely

Table 5 Initial reachability matrix

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1	1	0	1	0	0	1	1	0	1
HSCB2	1	1	1	1	0	0	1	1	0	1
HSCB3	0	0	1	0	0	0	1	0	0	0
HSCB4	0	1	0	1	0	0	0	0	0	0
HSCB5	0	0	1	0	1	1	0	1	1	1
HSCB6	1	1	0	1	0	1	1	1	0	1
HSCB7	0	0	1	1	0	0	1	0	0	1
HSCB8	0	0	0	0	0	0	0	1	0	0
HSCB9	0	0	0	0	0	1	0	0	1	1
HSCB10	1	1	0	1	0	0	0	0	0	1

Table 6 Final reachability matrix

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1	1	1*	1	0	0	1	1	0	1
HSCB2	1	1	1	1	0	0	1	1	0	1
HSCB3	0	0	1	1*	0	0	1	0	0	1*
HSCB4	1*	1	1*	1	0	0	1*	1*	0	1*
HSCB5	1*	1*	1	1*	1	1	1*	1	1	1
HSCB6	1	1	1*	1	0	1	1	1	0	1
HSCB7	1*	1*	1	1	0	0	1	0	0	1
HSCB8	0	0	0	0	0	0	0	1	0	0
HSCB9	1*	1*	0	1*	0	1	1*	1*	1	1
HSCB10	1	1	1*	1	0	0	1*	1*	0	1

The values marked with * indicates transitivity

Table 7 Level partitioning

Barriers	Reachability set	Antecedent set	Intersection set	Level
HSCB 1	1, 2, 3, 4, 7, 8, 10	1, 2, 4, 5, 6, 7, 9, 10	1, 2, 4, 7, 10	II
HSCB 2	1, 2, 3, 4, 7, 8, 10	1, 2, 4, 5, 6, 7, 9, 10	1, 2, 4, 7, 10	II
HSCB 3	3, 4, 7, 10	1, 2, 3, 4, 5, 6, 7, 10	3, 4, 7, 10	I
HSCB 4	1, 2, 3, 4, 7, 8, 10	1, 2, 3, 4, 5, 6, 7, 9, 10	1, 2, 3, 4, 7, 10	II
HSCB 5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	5	5	IV
HSCB 6	1, 2, 3, 4, 6, 7, 8, 10	5, 6, 9	6	II
HSCB 7	1, 2, 3, 4, 7, 10	1, 2, 3, 4, 5, 6, 7, 9, 10	1, 2, 3, 4, 7, 10	I
HSCB 8	8	1, 2, 4, 5, 6, 8, 9, 10	8	I
HSCB 9	1, 2, 4, 6, 7, 8, 9, 10	5, 9	9	III
HSCB 10	1, 2, 3, 4, 7, 8, 10	1, 2, 3, 4, 5, 6, 7, 9, 10	1, 2, 3, 4, 7, 10	II

high influence, low influence, medium influence, etc. Thus, to match the real-life scenario, we evaluated the influence using a seven-point trapezoidal neutrosophic scale, as shown in Table 8.

All six experts were asked to rate the level of influence between the barriers based on the seven-point neutrosophic scale shown in Table 8. Thus, the final reachability matrix shown in Table 6 is modified to the neutrosophic reachability matrix. The value '1' in Table 6, showing the influence between the barriers, is replaced with the linguistic terms provided in Table 8. All six experts provided their individual judgments, thereby creating six judgment matrices. The sample judgment matrix for Expert-1 demonstrating the level of influence between the barriers using linguistics terms is shown in Table 9.

Once the judgment matrix with the linguistic scale is obtained for individual experts, the linguistics terms are replaced by the respective SVTrNN number, as shown in Table 8, to get a neutrosophic judgment matrix. Thus, we got six neutrosophic judgment matrices for each expert. The sample neutrosophic judgment matrix for expert-1 is provided in Table 10.

After obtaining neutrosophic matrices for all the experts, the deneutrification process is conducted to gain crisp values for further analysis. A score function proposed by Pamucar et al. (2020) is utilized to obtain the crisp scores from neutrosophic numbers. The score function is given as—

$$S(\tilde{p}) = \frac{1}{3}\left\{2 + \frac{(p_1 + p_2 + p_3 + p_4)}{4} - \frac{(q_1 + q_2 + q_3 + q_4)}{4} - \frac{(r_1 + r_2 + r_3 + r_4)}{4}\right\} \quad (8)$$

After applying Eq. (8) on neutrosophic judgment matrices of all experts, the deneutrified judgment matrix will be obtained for all six experts. The deneutrified matrix for expert-1 is shown in Table 11.

Finally, a geometric mean of deneutrified judgment matrices of all the experts is computed to aggregate the judgments for evaluating the driving and dependence power of each barrier. The geometric mean is a widely used approach to aggregate the judgments. Geometric mean captures the variability associated within the data. Therefore, it is considered the most appropriate method to combine the judgments (Hummel et al., 2014). The aggregated judgment matrix is given in Table 12. Further, we classified the HSC operationalization barriers into four clusters—autonomous barriers, dependent barriers, linkage barriers, and independent barriers based on the driving and dependence power using a MICMAC (Matrice d'Impacts

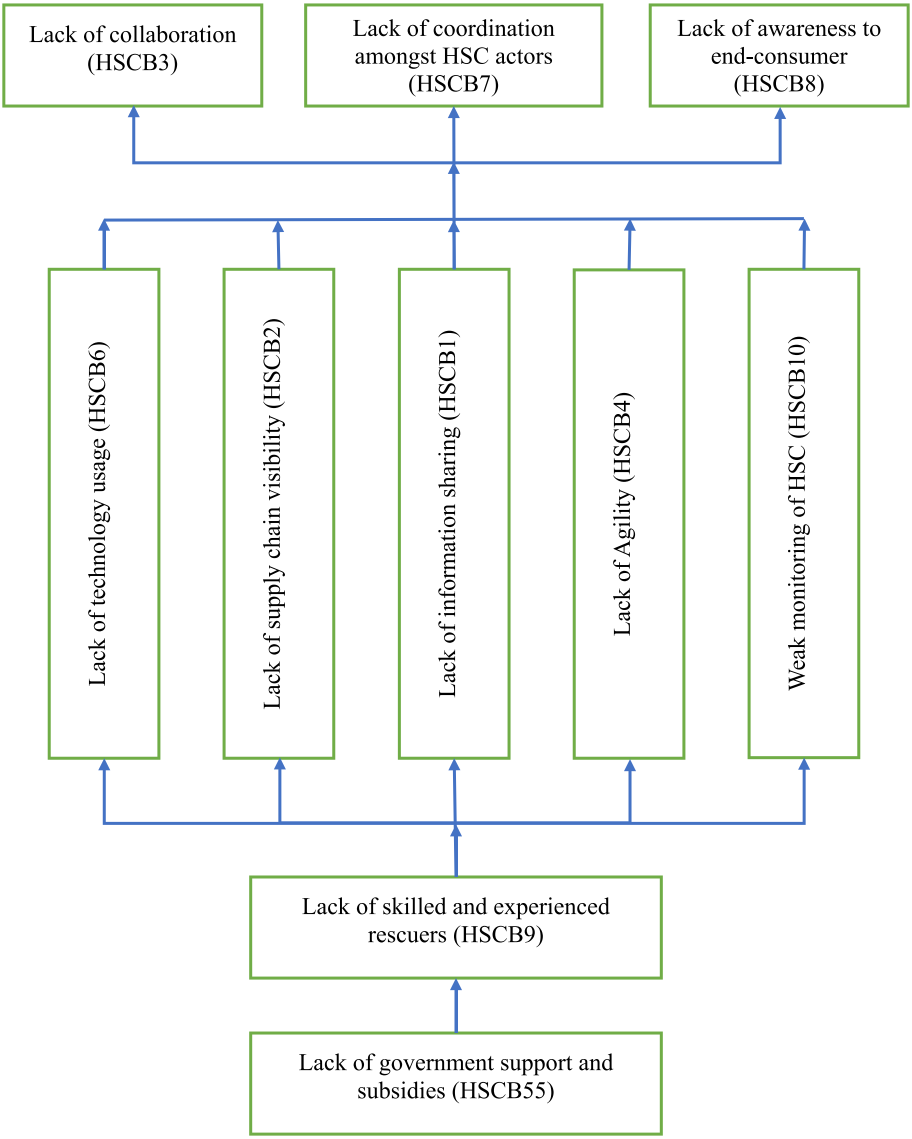

Fig. 3 Diagraph of HSC barriers

Croisés Multiplication Appliqués à un Classement) analysis (Majumdar et al., 2021). The cluster diagram of HSC operationalization barriers is shown in Fig. 4.

4 Discussion of the findings and recommendations

This study manifested the successful implication of a Delphi method followed by a novel neutrosophic ISM technique to analyze the barriers to the operationalization of HSC during

Table 8 Neutrosophic Seven-Point Scale (Pamucar et al., 2020)

Linguistic terms	SVTrNN number
Absolutely high (AH)	(0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1)
High (H)	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)
Fairly high (FH)	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)
Medium (M)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)
Fairly low (FL)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)
Low (L)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)
Absolutely low (AL)	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)

COVID-19 in India. A total of 10 critical HSC barriers are retained for the analysis purpose of this study, which are identified using an extensive literature review and confirmed by a Delphi technique using experts' opinions. These 10 HSC barriers are further subjected to neurotrophic ISM to determine the interrelationship patterns between them and identify the 'driving and dependence' powers, which helps determine the critical barriers.

Based on the level partitioning of the barriers, we obtained a digraph of HSC operationalization barriers, as shown in Fig. 3. The digraph comprises four levels. The four levels are clustered into three groups as—top-level, intermediate, and bottom-level barriers. The bottom-level barriers are those which are highly influential and impacts other barriers severely. The digraph depicts, lack of government support and subsidies (HSCB5) and lack of skilled and experienced rescuers (HSCB9) are the barriers at the bottom level, i.e., level IV and III of a digraph. These barriers drive the intermediate barriers, namely—lack of technology usage (HSCB6), lack of supply chain visibility (HSCB2), lack of information sharing (HSCB1), and lack of agility (HSCB4), weak monitoring of HSC (HSCB10). Whereas lack of collaboration (HSCB3), lack of coordination amongst HSC actors (HSCBB7), and lack of awareness to end-consumers (HSCB8) are the top-level barriers in a digraph. The top-level barriers have the least influence and largely depend on the other barriers. The stakeholders, policymakers, and Government authorities must focus on the bottom-level barriers to mitigate the problems to streamline the HSC operations. Further, using the driving and dependence power of all the 10 barriers, we classified them into four clusters using a MICMAC analysis as shown in Fig. 4. the MICMAC analysis is discussed next.

4.1 Autonomous barriers

Barriers having lower driving and dependence powers are clustered as autonomous barriers. The barriers in this category have significantly low influence and can be easily tackled. The nature of the COVID-19 pandemic is highly unpredictable. This pandemic has imposed a unique set of obstructions to HSC. Thus, scientists, medical authorities, and Government organizations around the globe have failed to predict the measures to tackle the COVID-19 challenges. This is why, each barrier is influential with different nature, and it was difficult to tackle barriers easily. Thus, in the present research work, no autonomous barriers are found.

Table 9 Judgment matrix using neutrosophic linguistic scale for Expert-1

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1	AL	L	FL	NO	NO	AL	AL	NO	AL
HSCB2	L	1	L	M	NO	NO	L	M	NO	M
HSCB3	NO	NO	1	AL	NO	NO	M	NO	NO	FH
HSCB4	M	L	FL	1	NO	NO	FH	FL	NO	FH
HSCB5	M	L	H	M	1	AH	FH	H	AH	H
HSCB6	H	FH	L	M	NO	1	FL	FH	NO	H
HSCB7	FL	M	FL	L	NO	NO	1	NO	NO	FL
HSCB8	NO	NO	NO	NO	NO	NO	NO	1	NO	NO
HSCB9	FH	L	NO	H	NO	FH	M	FL	1	H
HSCB10	FH	AL	AL	L	NO	NO	H	FH	NO	1

Table 10 Neutrosophic judgement matrix for Expert-1

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	0	0	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	0	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)
HSCB2	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	1	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	0	0	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	0	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)
HSCB3	0	0	1	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	0	0	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	0	0	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)
HSCB4	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	1	0	0	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	0	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)

Table 10 (continued)

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB5	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	1	(0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1)	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)	(0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1), (0.1, 0.1, 0.1, 0.1)	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)
HSCB6	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	0	1	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	0	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)
HSCB7	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	0	0	1	0	0	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)
HSCB8	0	0	0	0	0	0	0	1	0	0

Table 10 (continued)

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB9	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	0	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)	0	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7), (0.2, 0.4, 0.5, 0.7)	(0.5, 0.6, 0.7, 0.8), (0.4, 0.6, 0.7, 0.9), (0.4, 0.6, 0.7, 0.9)	1	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)
HSCB10	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	(0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9)	(0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9), (0.7, 0.8, 0.9, 0.9)	0	0	(0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3), (0.1, 0.1, 0.2, 0.3)	(0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4), (0.1, 0.2, 0.3, 0.4)	0	1

Table 11 Deneutrified judgement matrix for Expert-1

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10
HSCB1	1.0000	0.3667	0.3917	0.4500	0.0000	0.0000	0.3667	0.3667	0.0000	0.3667
HSCB2	0.3917	1.0000	0.3917	0.5167	0.0000	0.0000	0.3917	0.5167	0.0000	0.5167
HSCB3	0.0000	0.0000	1.0000	0.3667	0.0000	0.0000	0.5167	0.0000	0.0000	0.5833
HSCB4	0.5167	0.3917	0.4500	1.0000	0.0000	0.0000	0.5833	0.4500	0.0000	0.5833
HSCB5	0.5167	0.3917	0.6083	0.5167	1.0000	0.6333	0.5833	0.6083	0.6333	0.6083
HSCB6	0.6083	0.5833	0.3917	0.5167	0.0000	1.0000	0.4500	0.5833	0.0000	0.6083
HSCB7	0.4500	0.5167	0.4500	0.3917	0.0000	0.0000	1.0000	0.0000	0.0000	0.4500
HSCB8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
HSCB9	0.5833	0.3917	0.0000	0.6083	0.0000	0.5833	0.5167	0.4500	1.0000	0.6083
HSCB10	0.5833	0.3667	0.3667	0.3917	0.0000	0.0000	0.6083	0.5833	0.0000	1.0000

Table 12 Aggregated judgement matrix

Barriers	HSCB1	HSCB2	HSCB3	HSCB4	HSCB5	HSCB6	HSCB7	HSCB8	HSCB9	HSCB10	Driving power
HSCB 1	1.0000	0.4203	0.3836	0.4013	0.0000	0.0000	0.3874	0.4249	0.0000	0.3707	3.3882
HSCB 2	0.3748	1.0000	0.3790	0.4106	0.0000	0.0000	0.4249	0.4249	0.0000	0.4106	3.4248
HSCB 3	0.0000	0.0000	1.0000	0.3707	0.0000	0.0000	0.5272	0.0000	0.0000	0.5602	2.4581
HSCB 4	0.5049	0.4013	0.4500	1.0000	0.0000	0.0000	0.5641	0.4499	0.0000	0.5586	3.9289
HSCB 5	0.5490	0.5137	0.5879	0.5528	1.0000	0.6333	0.5833	0.6083	0.6333	0.6082	6.2699
HSCB 6	0.6041	0.5957	0.4102	0.5272	0.0000	1.0000	0.4397	0.5717	0.0000	0.6082	4.7568
HSCB 7	0.4604	0.4659	0.4008	0.4249	0.0000	0.0000	1.0000	0.0000	0.0000	0.5152	3.2673
HSCB 8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
HSCB 9	0.5490	0.4711	0.0000	0.6041	0.0000	0.5874	0.5167	0.4499	1.0000	0.6041	4.7823
HSCB 10	0.5874	0.4401	0.3707	0.4008	0.0000	0.0000	0.6041	0.5602	0.0000	1.0000	3.9634
Dependence power	4.6297	4.3081	3.9822	4.6926	1.0000	2.2208	5.0474	4.4898	1.6333	5.2359	37.2397

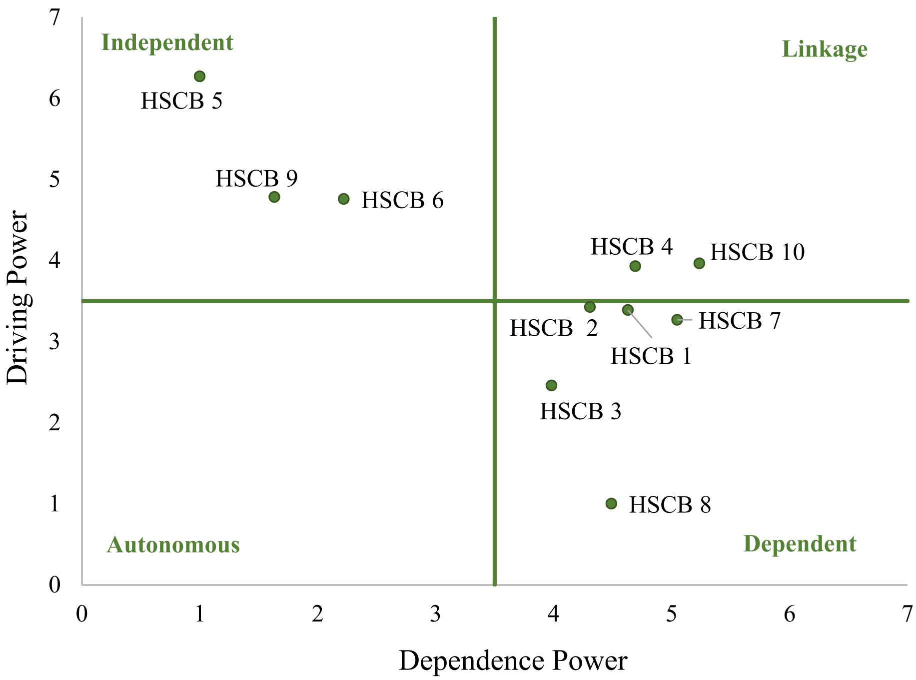

Fig. 4 Cluster analysis of HSC barriers

4.2 Dependent barriers

These barriers are highly dependent on the other barriers and possess high dependence and low driving power. These can be treated as the outcomes an organization is desired to achieve. In this study, the barriers—lack of information sharing (HSCB1), lack of supply chain visibility (HSCB2), and lack of collaboration (HSCB3), lack of coordination amongst HSC actors (HSCB7), and lack of awareness to end-consumer (HSCB8) are found under this cluster.

4.3 Linkage barriers

The barriers having a high driving and dependence power are called linkage barriers. The barriers under this category are unstable and can be influenced by other barriers. The fewer linkage barriers make an ISM model stable and robust to replicate in real-life cases (Majumdar & Sinha, 2019). Through a MICMAC analysis, we identified only two barriers falling under linkage type, namely—lack of Agility (HSCB4) and weak monitoring of HSC (HSCB10). The linkage barriers tend to create a feedback effect in the model (Chang et al., 2013) and shall be resolved carefully to smoothen the HSC operations.

4.4 Independent barriers

These are the most influential barriers having high driving and low dependence power. Being the major drivers, such barriers require enormous consideration from the decision-makers.

In the present study, lack of government support and subsidies (HSCB5), lack of technology usage (HSCB6), and lack of skilled and experienced rescuers (HSCB9) are induced as the significant independent barriers possessing a strong driving strength to obstruct the HSC operations. These barriers need serious attention from all the stakeholders to expedite the HSC operations.

As evident from the aforementioned analysis and the digraph, lack of government support and subsidies (HSCB5) has emerged as the critical barrier that impedes HSC operations. Apart from this, lack of technology usage (HSCB6) and lack of skilled and experienced rescuers (HSCB9) shall be critically examined by HSC practitioners, rescuers, and policymakers. The role of government support in smoothening the HSC is crucial. The government should bring the policies, rules, and tactics to create coordination between different HSC actors, namely—NGOs, organizations, sections, institutes, etc. (Ghasemian Sahebi et al., 2017; John & Ramesh, 2016).

Further, the government should foster policies to encourage the rescuers and end-consumers (i.e., survivors) to adopt technologies for adequate and accurate information sharing. The government shall provide financial support or subsidies to NGOs and private organizations participating in the COVID-19 relief-aid. The use of smart technologies such as artificial intelligence, big-data, RFID, and blockchains are effective in tracking the patient history and increasing transparency and accountability in HSC (Dubey, Gunasekaran, Childe, et al. 2019; Dubey, Bryde, et al., 2020; Dubey, Gunasekaran, et al., 2020; Kumar & Singh, 2021; Ozdemir et al., 2021; Rodríguez-Espíndola et al., 2020). This, in turn, assists in managing the aid and support to beneficiaries and patients effectively. Further, technology use improves information sharing within HSC and increases visibility within HSC players about the disaster conditions and availability of aid (John & Ramesh, 2016). The usage of different technology-oriented apps and internet-based systems can provide necessary information regarding the availability of beds for the infected patients, availability of vaccination slots, availability of oxygen concentrators, etc. to the beneficiaries and patients. GOI launched the "Arogya Setu" app to provide the information and tracking history of the COVID-19 infectants. Further, the "CoWIN" app and website is used to get information related to check and book the available vaccination slots ("Arogya Setu" 2021). Despite that, due to inadequate training, available data and information sharing, the patients, beneficiaries, survivors, and benefactors fails to find the usefulness of these online platforms (Times of India, 2021).

As the COVID19 disaster is unforeseen, the skillsets required from humanitarian rescuers are unique. Being the rescuers are obscured with the pandemic nature, the GOI shall impart training sessions for rescuers involving technology usage, agility in providing aid, emergency medical services for the patients, etc. to make them readily available for disruptive situations. Thus, skilled rescuers can effectively monitor the operations of HSC through appropriate technology usage. This, in turn, improves the collaboration, coordination, visibility, and agility within HSC. Further, appropriate coordination between HSC actors and technology-oriented systems can provide sufficient information to end-consumers (beneficiaries) to increase awareness about the situations of the COVID-19 outbreak and the availability of relief aids.

5 Research implications

The proposed research has several implications to the theory and practice of the HSCM domain. The results and recommendations provided in this study facilitate practitioners and policymakers to develop novel strategies for smoothening the operations of HSC during pandemic times.

5.1 Theoretical implications

The theoretical contribution of the present study is three-fold. Firstly, this research is a primitive study that identified and analyzed barriers impacting the operationalization of HSC posed due to the COVID-19 outbreak. Secondly, the present research work identified 10 critical barriers that obstruct the streamlined HSC operations in Indian context during the COVID-19 and provides recommendations to mitigate them. Thirdly, the notable implication of the present research to the theory is developing a novel form of ISM, i.e. Neutrosophic ISM. The present study is pioneered to develop a neutrosophic ISM and further demonstrate its applicability to the actual problem. The neutrosophic ISM is utilized to determine the interrelationships amongst the barriers and compute the driving and dependence power to determine the criticality of barriers. The combination of neutrosophic theory with ISM aids in overcoming the disadvantages associated with other ISM types (as discussed in Table 3).

5.2 Managerial implications

The present research offers significant managerial implications for the practitioners, policymakers, and professionals involved in humanitarian organizations. The practitioners and policymakers can understand the prominent barriers to HSC operations owing to pandemic situations that restrict the flow and agility of humanitarian relief-aid to the beneficiaries. The hierarchical model of the barriers, i.e. digraph developed in the present research, can provide insights into the most influential HSC barriers. The recommendations provided can guide the practitioners, professionals, stakeholders, policymakers, NGOs, and government authorities actively participating in humanitarian relief operations during the pandemic to understand policies for effective management and flow of relief aid. The findings of the present research suggested that appropriate "government support and subsidies, skilled rescuers and technology usage" for communicating necessary information can enhance the agility, coordination of HSC players, cooperation, visibility in HSC, and awareness to end-consumers.

6 Conclusion, limitations, and future research opportunities

The humanitarian supply chain management plays a crucial role in providing relief-aid to disaster-hit beneficiaries. The effectively managed humanitarian supply chains and logistics are the core components that enable the steady and constant flow of aid. Any malfunctioning of HSCs due to unanticipated barriers resulted in disturbances and delays in the aid provisions. Thus, HSCM has received enormous attention in the literature from the researchers and in practice from policymakers, practitioners, government bodies, organizations, etc. The current disastrous ambiance created due to COVID-19 pandemic havoc disrupted the livelihoods worldwide. These unforeseen situations resulted in record levels of humanitarian relief needs globally. This triggers a growing interest in managing effective humanitarian support through HSCs during the COVID-19. However, the COVID-19 pandemic, due to its ambiguous nature, induced major hurdles to the functioning of HSC. The present research work attempts to identify and analyze the critical barriers intervening the HSC operations that emerged during COVID-19 in India. We identified and validated 10 critical HSC operationalization barriers through a comprehensive review of existing literature followed by a Delphi technique. Thereafter, a novel Neutrosophic ISM technique is formulated by combining conventional ISM with the neutrosophic theory to determine the interrelationship and 'driving and dependence power' of HSC barriers. Further, a digraph is created using level partitioning in which the barriers are structured in different levels based on their influence. The identified 10 HSC barriers are clustered in four categories (autonomous, dependent, linking, and independent) using their driving and dependence power through MICMAC analysis.

The results indicated that lack of government support and subsidies (HSCB5), lack of skilled and experienced rescuers (HSCB9), and lack of technology usage (HSCB6) are found to be the independent barriers. These are the most influential HSC barriers and significantly drive all other barriers. Lack of information sharing (HSCB1), lack of supply chain visibility (HSCB2), and lack of collaboration (HSCB3), lack of coordination amongst HSC actors (HSCB7), and lack of awareness to end-consumer (HSCB8) are identified as dependent barriers having the highest dependency and least driving power. Only two barriers are found as linkage barriers, implying the model is well stable (Majumdar et al., 2021). The linkage barriers are—lack of Agility (HSCB4) and weak monitoring of HSC (HSCB10). The independent barriers are the most significant, and it is crucial and strategically essential to mitigate these driving barriers for effective HSC operations and enhance the agility in the relief-aid. Further, the results and recommendations of this research work provide valuable insights for practitioners, stakeholders, and policymakers for successful HSC operations to provide humanitarian needs.

6.1 Limitations and future research opportunities

The present research work comprises certain limitations which can be pursued in future studies. This work pertains to the HSCs within India. The impact of barriers to HSC operationalization may vary from country to country (Karuppiah et al., 2021). Besiou and Van Wassenhove (2020) stated that there exist considerable differences in disaster response between developed and developing countries. Thus, similar studies can be performed in the HSCs of other developed and developing economies. It would be interesting to determine the changes in the patterns of these barriers concerning different localities through a comparative assessment. This research work has utilized the expertise of 6 respondents to retrieve the knowledge about the HSC barriers. Future studies shall include more experts (greater than 6) from different HSC backgrounds, including academia, industry, NGOs, military, etc. to examine the HSC barriers to get the panoramic view of the problem under study. The future work shall conduct case study based research concerning HSCs by utilizing the MCDM approach, optimization tools, or machine learning algorithms to gain deeper understandings about the behavior of barriers in real-life cases. Predictive analytical scenarios can be created through simulating real-life cases for efficiently forecasting the HSC operations to manage effective relief-aid. The novel Neutrosophic ISM is a flexible approach. It can be generalized to analyze the barriers, factors, risks, enablers, critical success factors, performance measures of implementing other aspects, viz. lean implementation, industry 4.0 implementation, blockchain adoption, etc., in the different domains. The current pandemic of COVID-19 has created awareness regarding resiliency in supply chains (Dohale, Ambilkar, et al., 2021; Dohale, Gunasekaran, et al., 2021; Dohale, Verma, et al., 2021). Thus, future studies shall focus on creating a robust framework that can effectively create resilient humanitarian supply chains utilizing smart technologies. The present study was conducted during the COVID-19 pandemic. It could be possible that the nature of these barriers may vary, or an entirely new set of challenges can be seen in post-COVID-19 situations. Thus, future studies shall explore and analyze the barriers to HSC operationalization of HSCs post-pandemic conditions.

Note: The judgment matrices, neutrosophic matrices, deneutrified matrices for all experts are provided in Supplementary File.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10479-022-04752-x.

Appendix: Description of the barriers to HSC operations

Barrier	Description	References
Lack of information sharing	Sharing information is necessary for humanitarian supply chain management. Information sharing increases the agility, visibility, and flexibility of HSC. Lack of information sharing leads to inefficient HSC	Dubey Bryde, et al. (2020), John and Ramesh (2016), Ozdemir et al. (2021), Patil et al. (2021), Prasanna and Haavisto (2018)
Lack of supply chain visibility	Supply chain visibility improves operational effectiveness, responsiveness, and overall performance of HSC. Lack of supply chain visibility results in inefficient and inflexible demand–supply management and leads to susceptible, intricate, and costly HSC operations	Dubey et al. (2021), Dubey, Bryde, et al. (2020), Dubey, Gunasekaran, et al. (2020)), John and Ramesh (2016), Maghsoudi and Pazirandeh (2016)
Lack of collaboration	Collaboration is a critical factor for success in HSC. Collaboration helps improve overall response efficiency and timely supply by exchanging information, knowledge, and resources to manage HSC. A lack of collaboration in HSC could result in ineffective responses and disastrous consequences	Dubey et al. (2021), Ghasemian Sahebi et al. (2017), John and Ramesh (2016), Prasanna and Haavisto (2018)
Lack of Agility	Agility grants a quick reaction in unexpected conditions. Agility in HSC helps to move relief-aid proficiently and adequately to disaster-affected sites. Lack of agility slower down the response rate in HSC	Dubey, Bryde, et al. (2020), Dubey, Gunasekaran, et al. (2020)), Ghasemian Sahebi et al. (2017), John and Ramesh (2016)

Barrier	Description	References
Lack of technology usage	Technology plays a key role in the HSC to communicate and share the essential information that helps deploy resources to provide effective relief in disaster areas. Lack of technology usage slower the information sharing to the rescuers and beneficiaries	Duong and Chong (2020), John and Ramesh (2016), Ozdemir et al. (2021), Prasanna and Haavisto (2018)
Lack of Government subsidies and support	Government plays an essential role in all challenging conditions, and the subsidies and supports help the entire supply chain to grow. Lack of government subsidies and supports can cripple the whole HSCs by increasing the financial burden over them	Dubey, Bryde, et al. (2020), Dubey, Gunasekaran, et al. (2020)), Ghasemian Sahebi et al. (2017), John and Ramesh (2016)
Lack of coordination amongst HSC actors	Coordination amongst HSC actors brings people together with experience, expertise, excellence, and capabilities to handle disastrous situations. The lack of coordination results in ineffective aid distribution to competition among actors for scarce resources and congestion at transportation networks	Amirhose and Pilevari (2021), Dubey, Bryde, et al. (2020), Dubey, Gunasekaran, et al. (2020)), Karuppiah et al. (2021), Prasanna and Haavisto (2018)
Lack of awareness to end-consumer	Lack of awareness among people on medical-related misbeliefs and myths aids containing the spread of disease. Lack of awareness usually led to the strenuous relationship amongst HSC partners and end-consumers	Ghasemian Sahebi et al. (2017), Karuppiah et al. (2021), Patil et al. (2020)
Lack of skilled and experienced rescuers	There is a scarcity of rescuers with adequate technical skillsets and expertise to operate and run the smart technology-enabled systems and communicate necessary information with an entire HSC	Ghasemian Sahebi et al. (2017), Karuppiah et al. (2021), Patil et al. (2020)
Cultural Context	The cultural context barriers in HSC are related to the discrepancies within HSC players. Due to the involvement of government, non-government, and private partners, a cultural gap between them is observed which may create misunderstandings and counterproductive efforts	Amirhose and Pilevari (2021), Balcik et al. (2010), Ghasemian Sahebi et al. (2017), Schulz (2009)

Barrier	Description	References
Difficulty in enforcing the rules	Enforcement of rules is an aspect of managing HSC that deals with forcing regulatory measures for disaster control. However, the enforcement results in the violation of the rules and resulting in damage to humanitarian supplies	Dubey et al. (2021), Hashemi Petrudi et al. (2020), Prasanna and Haavisto (2018)
Lack of swift trust	Swift trust is the willingness to rely upon HSC partners to perform their functions in disastrous situations. The swift trust is crucial in enhancing the coordination among HSC partners to provide disaster relief-aid	Dubey, Altay, et al. (2019), Dubey et al. (2019b), Dubey Gunasekaran, and Papadopoulos (2019)), Dubey, Bryde, et al. (2020), Dubey, Gunasekaran, et al. (2020)), Duong and Chong (2020)
Lack of commitment	Commitment improves the coordination amongst the HSC players. Commitment leads to improving reliability in the relationship and enhances the satisfaction and performance of HSC players	Amirhose and Pilevari (2021), Dubey et al. (2021), Dubey, Altay, et al. (2019), Dubey et al. (2019b), Dubey Gunasekaran, and Papadopoulos (2019)), Duong and Chong (2020), Prasanna and Haavisto (2018)
Weak monitoring of HSC	Lack of coordination is a vital problem in HSCs. Many humanitarians implied or even stated that allowances are often made for weak monitoring and evaluation between actors and donors due to the remote management system	Hashemi Petrudi et al. (2020), Ozdemir et al. (2021)

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