Towards understanding key enablers to green humanitarian supply chain management practices

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Abstract

Purpose – Humanitarian supply chains (HSCs) by their very nature require urgent reaction to unforeseeable needs, making it difficult to properly plan for the support of actual demands. As such, integrating sustainability into traditional HSC practices continues to present a challenge to governments, nongovernmental organizations (NGOs) and other humanitarian-related agencies. This study focuses on identifying and categorizing the leading enablers to green humanitarian supply chains (GHSCs) and proposes a model for improving the responsiveness based upon a fuzzy total interpretive structural modelling approach.

Design/methodology/approach – Total interpretive structural modelling (TISM) uses group decision-making to identify contextual relationships among each pair of enablers and elucidates the nature of each underlying relationship. The fuzzy TISM shows the level of strength (very high influence, high influence, low influence and very low influence) of each enabler in relation to other enablers, which can help to inform management decision-making.

Findings – GHSC management requires strategic planning of inventory and logistics management. The importance of collaborative relationship building with HSC partners for developing capability and the effective use of available resources are keys to success. These improved relationships also help to promote postponement and similar speculation-based logistics strategies, as well as advanced purchasing and pre-positioning strategies. Finally, the speed and quality of response is found to be the top enabler in GHSC management.

Research limitations/implications – One noted shortcoming of the chosen research method is its reliance on subjective expert judgement. However, collecting judgements is at the basis of many research methods, and the research team took utmost care throughout the research process to allay biases. Future empirical research can further examine the relationships suggested herein. Managers can use the model developed in this research to consider impactful ways to design and execute sustainable HSCs.

Originality/value – To the best of the authors' knowledge, this is a novel attempt to identify enablers to GHSC management. Secondly, the research team has used an advanced methodology (fuzzy TISM) to develop the contextual inter-relationships among the enablers which has not been used earlier in this direction before and thus advances the GHSC literature.

Keywords Enablers, Green, Humanitarian supply chain (HSC), MICMAC, South Africa, Sustainability, Fuzzy total interpretive structural modelling (fuzzy TISM)

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1. Introduction

On 28 September 2018, a 7.5-magnitude earthquake triggered a tsunami which caused serious devastation in the coastal area of Palu region in Indonesia. It has taken away life of 1,500 humans, leaving more than 70,000 people homeless. However, this is not an end to the pain and sufferings; it became worse when the Soputan Volcano in the Northern part of Sulawesi, Indonesia, erupted on 3rd October same year, emitting volcanic ash as high as 4,000 m into the air. Typically, such disasters leave huge volume of waste (building rubbles, soil and debris, fallen trees, hazardous elements, remnants of human and animal corpses) in the surrounding, causing high environmental impact (United Nations Environment, 2018 report). This reminded humanitarian organizations to make sure that environmental proficiency is incorporated in the existing disaster response mechanisms.

During the post–natural disaster event, the biggest problems in front of human race are not only those short-term sufferings but mainly the long-term consequences which raise a concern towards sustainability. The common problems associated with post-disaster events are sanitation, drinking water pollution, disease, lack of fertile farmland, deforestation and soil erosion, clearing away general waste, medical waste and high level of debris which requires scientific way of disposal, migration of homeless groups to other locations leading to premature death, civil unrest and wars between different groups (John, 2018; Mackay *et al.*, 2019). Environmental experts have explained disasters through the popular butterfly effect which indicates that events such as earthquakes may generate a chain of other events such as floods, landslides, epidemics and drought in the affected areas, and we have noticed this from the Indonesia earthquake case as well. Mainly, environmental and social concerns have led to generation of the concept of green humanitarian supply chains (GHSCs) which involve integration of environmental, social and economic dimensions in the traditional humanitarian supply chain (HSC) network. If we look at the global disaster-relief reports, we find that there is always some kind of issues which have occurred during disaster-relief operations. The GHSC aims at reducing uncertainties and improving responsiveness and resilience (Sarkis *et al.*, 2012; Kunz and Gold, 2017). The key characteristics of a GHSC design are agility, adaptability and alignment, which is popularly known as triple "*A*" (Dubey and Gunasekaran, 2016).

Kunz and Gold (2017) suggested that alignment of a supply chain design corresponding to relief organization enablers is not only important but is equally important to align it with the long-term requirement of the population and related socio-economic and governmental contingency factors for a GHSC.

Regardless of the sources of humanitarian aid in the HSC or triple "*A*" mechanism, the question still remains: Are current HSC practices green? What are the enablers to green HSC? What are the inter-relationships among these GHSC enablers? How can these links be interpreted, under which context?

Our research is thus driven by three central research objectives.

RQ1. To identify the enablers of the GHSC.

RQ2. To develop inter-relationships among the GHSC.

RQ3. To develop a framework for guiding HSC managers in deploying the GHSC.

The current study is motivated in large part by the limitations and future research directions suggested by Sarkis *et al.* (2012), whose research identified several important factors influencing green HSC development. As noted by Sarkis *et al.* (2012), HSC is a dynamic and quickly evolving area of practical significance, and additional factors beyond those considered in the extant HSC literature need to be identified and studied. We developed this current research to explore such factors. We used an interpretive technique to generate theory through multiple interactions with HSC experts and build knowledge in this direction.

Therefore, this research aims to fill the gap in existing literature and extend the knowledge base in GHSCs.

The paper is organized as follows. The second section covers the review of relevant literature, followed by section three on research methodology and analysis overview. The results and discussions are presented in section four. Conclusions, social implications, unique contributions, limitations and future research directions are discussed in the final section.

2. Literature review

Literature review is considered to be the most critical part of any research work. The output of literature review is strongly affected by the articles considered for the review. Hence, it is extremely essential to follow a scheme for systematic literature review. The present study adopts the literature review scheme followed by Tranfield *et al.* (2003), Yadav and Desai (2016) and Yadav *et al.* (2018) for analyzing the selected articles. Accordingly, an attempt has been made to understand the progress which has happened in the field of HSC, considering selected studies from recent years. The Sendai framework is the first of the world's post 2015 development agreements which act as a tool to accomplish the HSC sustainability objectives. It was followed by three other major intergovernmental agreements such as the Addis Ababa Action Agenda on financing for development in July 2015; Transforming our World: the 2030 Agenda for Sustainable Development which was accepted in September 2015 and the December 2015 Paris Agreement on Climate Change (Source: https://www.unisdr.org/).

Apart from these agreements, various awards such as "UN Sasakawa Award" and "The 2017 risk award" has been declared for disaster risk reduction to honour an individual or organization, whosoever has played an important role in saving human lives and reducing disasters. Therefore, it is notable that with time, the role of GHSC management in disaster risk reduction is increasing and attracting attention of policymakers, practitioners and researchers.

The basic attributes of an HSC that makes HSC operations complex are unpredictability of demand, sudden demands of high volume for a wide range of items, specialized logistics channel requirements, high level of uncertainty and high stakes associated with sufficient and well-timed delivery of supplies (Heintze and Zwitter, 2011; Caunhye *et al.*, 2012). HSC is further complicated due to involvement of dissimilar kind of actors in the decision-making process (Day *et al.*, 2012).

It is very important that humanitarian research studies are grounded upon some strong theoretical base. If we look into the existing literature, we find that some of the popular theories have been earlier used for HSC framework development such as stakeholder theory, supply network management, multilocation inventory theory, theory of constraints and management information systems theory (Jahre *et al.*, 2009; Kovács and Spens, 2007; Maon *et al.*, 2009; Tatham and Pettit, 2010; Apte, 2010; Kovács; Spens, 2011; Overstreet *et al.*, 2011). However, Tabaklar *et al.* (2015) have recently argued that there is evidence of increasing trend towards application of more well-known, "middle-range" theories. But the application of theoretical approaches is not homogenously covered between the various phases of the HSC. They further suggested using alternative theoretical perspectives in defining the HSC which means this field is still immature and requires more theoretical focus by future researchers.

Previous researchers have done few seminal works such as analysis of critical HSC success factors (Yadav and Barve, 2015), identification and prioritization of coordination barriers in HSC (Kabra *et al.*, 2015) and analysis of key factors for waste management in the HSC (Trivedi *et al.*, 2015). However, they remain far from establishing a holistic model for green HSC. Proper understanding of this subject is still lacking, and we identified the need to explore the inter-relationships so that robust GHSC models can be created by future researchers based on our research work.

2.1 Enablers of green humanitarian supply chain
An enabler is an element which facilitates another to achieve an end outcome (Santos *et al.*, 2016). We have attempted to classify the GHSC enablers under six categories such as informational enablers, human enablers, operational enablers, political enablers, economic enablers and technological enablers. The enablers are identified from extant literature and finalized after consultation with HSC experts. The nineteen enablers and sources are presented in Table 1.

2.1.1 Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data. Information and communication technology (ICT) is one of the key components for the humanitarian logistics operations (Kaiser *et al.*, 2003; Overstreet *et al.*, 2011).

Laituri and Kodrich (2008) argue the importance of GIS in the online disaster responses. It is imperative for the aid agencies to have compatible information along with the GIS assisted by the satellite data. This will lead to a sustained result in locating the distribution centres and designing the humanitarian logistics operations (Maspero and Itmann, 2008; Naji-Azimi *et al.*, 2012; Villa *et al.*, 2017). It further helps to investigate disease outbreak, design health information systems and monitor the performance of the disaster-relief systems as well (Kaiser *et al.*, 2003).

2.1.2 Early warning systems of potential hazards and continuous monitoring. Experts opined that early warning systems help the aid programs to have a sustainable strategy to counter the disasters using the sophisticated information system. Researchers also position the warning systems as an integral component in the disaster management cycle (ADB Report, 2004; Regnier, 2008; Tatham and Houghton, 2011). This is in line with the proposition given by Van Wassenhove (2006). It is also complemented by the disaster awareness training programmes and systems like tsunami warning systems, aiding the HSC professionals towards a good preparedness and mitigating the disasters (Kovacs and Spens, 2009). Besides, a continuous monitoring of humanitarian aid network would also help the stakeholders to effectively comanage the relief chains (Chands and Pache, 2010).

2.1.3 Awareness creation on sustainable practices in the HSC. Awareness on the best practices is an essential enabler to design sustainable operations (Geldermann, 2007; Nishat Faisal, 2010). The experts also concurred that having a deeper knowledge on the various practices would help HSC professionals to devise a long-term sustainable strategy. This is possible through various continuous training programmes and knowledge-sharing platforms across the globe by the major relief agencies such as Red Cross and UN agencies. On the other hand, it is a challenge to create the complete knowledge on the best sustainable practices as it can be constrained by other factors such as time, funding and availability of the support (Kovacs and Spens, 2011).

2.1.4 Learning from past disasters. For any sustainable disaster resilience plan, experience from the past disaster is an effective factor to be taken into account (Shaw and Goda, 2004; Salalama *et al.*, 2004: Smith and Wenger, 2007). On the other hand, by limiting the learning from past experience, focussing only on the short term would not facilitate the sustainable network development in the humanitarian operations (Goncalves, 2008).

Chandes and Pache (2010) also endorse the acquisition of the nuances of the past experience is an organized necessary task to design a sustainable resilience programme in any network. Participants in our study also concurred the importance of interpreting the nuances of the previous disasters would help the HSC professionals to design their network more agile and responsive.

2.1.5 Trust building among disaster affected people. Trust is a mandatory factor in any supply chain leading to sustainable operational excellence (Hoyt and Huq, 2000; Beske, 2012). Along the similar lines of commercial supply chains, it is important to create trust for sustainability in HSC operations as well (McLachlin and Larson, 2011). To be precise, it is not

Table I. Enablers to green HSC

Categories	No	Enablers	Source
Informational enablers	E1	Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data	ADB Report (2004), Overstreet *et al.* (2011)
	E2	Early warning systems of potential hazards and continuous monitoring	Delmonteil and Rancourt (2017)
	E3	Awareness creation on sustainable practices in HSC	Nishat Faisal (2010), Villa *et al.* (2017)
Human enablers	E4	Learning from past disasters	Eiser *et al.* (2012), Goffnett *et al.* (2013)
	E5	Trust building among disaster affected people	Beske (2012), Eiser *et al.* (2012)
Operational enablers	E6	Strategic planning to implement sustainable practices in HSC	Kovacs and Spens (2007), Nishat Faisal (2010), Nikbakhsh and Farahani (2011)
	E7	Collaborative relationships with HSC actors	McLachlin *et al.* (2009), Bag (2016), Bealt *et al.* (2016)
	E8	Metrics to quantify sustainability benefits in a HSC	Bowen *et al.* (2006), Beamon and Balcik (2008), Ahi and Searcy (2015)
	E9	Effective agreements with suppliers and service providers involved in HSC	Tatham and Pettit (2010), Santos *et al.* (2016)
	E10	Responsiveness (speed and quality)	Oloruntoba and Gray (2006), Jahre and Heigh (2008), Day *et al.* (2012)
	E11	Coordination of deliveries with counterparts in affected regions	Kovacs and Spens (2007), Akhtar *et al.* (2012), Li *et al.* (2019)
	E12	Meet minimum quality requirements of supplies	Stoddard (2006), Jahre and Heigh (2008)
	E13	Adoption of postponement/speculation logistics strategy	Jahre and Heigh (2008), Torabi *et al.* (2018)
	E14	Advance purchasing and pre-positioning	Lamenza *et al.* (2019), Turkeš and Sörensen (2019)
	E15	Logistics capability and resources	L'Hermitte *et al.* (2016), Maharjan and Hanaoka (2019), Heaslip and Stuns (2019)
Political enablers	E16	Regulatory framework	Halldórsson and Kovács (2010), Kunz and Reiner (2016)
Economic enablers	E17	Availability of funds and timely payments	Nishat Faisal (2010)
Technological enablers	E18	Advanced technology	Santos *et al.* (2016), Tatham *et al.* (2017)
	E19	Adequate equipment requirements and choice	Santos *et al.* (2016)

only necessary to have the trust among the supply chain partners, it is also important to establish it with the disaster-affected people, resulting in effective results of aid programs (Tatham and Kovacs, 2010). It would also help to reduce the community pressures, enabling the better performance of the HSC.

2.1.6 Strategic planning to implement sustainable practices in the HSC. For any effective humanitarian resilience programmes, strategic planning would help the organizations to look ahead by developing the right mitigating strategy and also optimize the entire supply chains at the leadership level (Kovacs and Spens, 2007; Nishat Faisal, 2010). All the disaster and emergency plans need to have the strategic approach in effectively managing the sustainable operations. Further, this approach could be by the collective approach of all the stakeholders involved in the HSC operations.

2.1.7 Collaborative relationships with HSC actors. To be more sustainable, organizations need to increase the collaborative partnerships to effectively handle all the supply chain risks. This could include the pre-positioning of the material, designing and managing the continuous-aid programmes through the joint efforts and focused investments with right operational strategy. This is to complement and balance the strengths of the stakeholders in the supply chains (McLachlin and Larson, 2011).

2.1.8 Metrics to quantify sustainability benefits in a HSC. Performance metrics giving a feedback loop to the stakeholders on the effectiveness of the HSC programs is an imperative element in any sustainable operations (Bowen *et al.*, 2006; Nishat Fasial, 2010; Ahi and Searcy, 2015). Taking that lead, experts also converged on the view that measurement is very crucial to establish sustainable HSCs. Also, they further elucidate that it is to be very useful for developing a region-specific HSC performance metric to build a performance-oriented network.

2.1.9 Effective contracts/agreements with suppliers and service providers involved in HSC. For any supply program, the effectiveness is highly influenced by the service-level agreements or contracts between the stakeholders (Santos *et al.*, 2016). This is very imperative particularly for the continuous-aid humanitarian programmes impacting the pre-positioning of the materials and distribution across the supply chain. Long-term agreements are highly effective in creating the sustainable ecosystem, though sometimes, it may not give minimum quantity assurance, yet it is a challenge for the aid professionals to maintain the relationships with the aid suppliers (Hilhorst, 2002). Also, enabling the collaborative procurement would also help to increase the effectiveness of the supply programmes and create sustainable operational ecosystem (Balcik *et al.*, 2010).

2.1.10 Responsiveness (speed and quality of response). The speed at which the disaster or humanitarian service is being obtained has always been a critical factor in a supply chain (Oloruntoba and Gray, 2006; Jahre and Heigh, 2008). This rapid deployment in an HSC is a combination of manufacturing and service supply chains responding at the earliest to the disaster sites (Luthra *et al.*, 2019).

Kovacs and Tatham (2009) cite the responsiveness in an HSC is effectively sustained through the regional hubs and interoperability among the various stakeholders. Besides, the speed at which the communication is being handled across the supply chain echelons also plays an important role in sustaining the performance in an HSC (Day *et al.*, 2012). Also, it is essential to oversee the information quality handled across the supply chains for the complete alignment of the supply chains to establish sustainable operations.

2.1.11 Coordination of deliveries with counterparts in affected regions. Humanitarian relief chains are often criticized for the lack of coordination among the stakeholders to establish sustainable operations (Kovacs and Spens, 2007). These coordination efforts may include right from the planning and continues till the last-mile delivery of the service or material delivery. NGOs, government agencies, United Nations establishments and local organizations are the very important stakeholders establishing the coordination in the supply chains. In addition, inventory pre-positioning requires a highest coordination among the stakeholders to have a fast response to the disaster-affected zones (Akkihal, 2006). Moreover, coordination in an HSC as a process leads to overcoming multiple complexities and challenges which ultimately helps to sustain the operations (Oloruntoba and Gray, 2006; Balcik *et al.*, 2010).

2.1.12 Meet minimum quality requirements of supplies. To sustain the operations in an HSC, along with the continuous supply of the materials, HSC supply chain should at least satisfy the minimum quality standards (Jhare and Heigh, 2008). In recent times, there are now increased expectations in the quality requirements from the stakeholders depending upon their supply chain position — either pre- or post-disaster spectrum. We also argue in the lines of Stoddard (2006) that meeting the minimum standards in the material quality would help to sustain the HSC operations.

2.1.13 Adoption of postponement/speculation logistics strategy. Postponement is aimed to avoid the anticipatory risk of supply chain requirements and delay the commitment in terms of product and time till the customers' orders arrive (Bowersox *et al.*, 1999). It is also considered as the strategy to sustain the operations in the commercial supply chains. In an HSC, more specifically in the continuous-aid supply programmes, postponement strategy would help to sustain the operations by lowering the operational costs (Jahre and Heigh, 2008). The strategic inventory handled in the chains would help sustain the operations (Oloruntoba and Gray, 2006).

2.1.14 Advance purchasing and pre-positioning. Pre-positioning of inventories in the designated zones or hubs is a direct enabler of sustaining the HSC operations. It has the strategic importance in HSC operations to effectively manage the continuous supply of the materials to the affected areas (Beamon and Kotleba, 2006; Duran *et al.*, 2013). For this, local sourcing and capacity building also play an important role (Kovacs and Spens, 2011). Also, it indirectly encourages the stakeholders to have a common and sustainable long-term approach in their HSC operations.

2.1.15 Logistics capability. Logistics expertise of the stakeholders is a design element in sustainable HSC (Tomasini and Van Wassenhove, 2009). Experts in our study also confirmed that this capability is an important skill of the participants/stakeholders in the HSC operations in terms of planning and execution. It includes their capacity to handle, be flexible and be aligned with respect to HSC needs. This would be augmented by the quality delivery fleets and their support systems including maintenance, trained workforce and continuous training programmes.

2.1.16 Regulatory framework. Regulatory framework with the policies and procedures are a very imperative component driving the supply chain sustainability (Linton *et al.*, 2007). In fulfilling those norms, HSC supply chain takes up the directives given by the governments, third-party standards and NGOs. This would enable HSCs to sustain the pressures from other stakeholders (Halldórsson and Kovács, 2010).

2.1.17 Availability of funds and timely payments. Nishat Faisal (2010) argues the importance of fund availability in driving the initiatives for sustainable practices. Though some of the activities in an HSC are voluntary, it is worth to acknowledge the funding is required for collecting the materials in the continuous-aid program or pre-positioning activities depending upon HSC priority. Participants in our study agreed on multiple avenues of indirect expenses in effectively running the HSC and that probability of destabilizing the sustainable activities is high without the proper fund flow both in upstream and downstream HSC operations.

2.1.18 Advanced technology. Apart from the ICT, there is a greater role for few other technologies in sustaining the operations. In HSCs, prominent of them are material handling, storage and packaging technology, which would directly impact the sustainability of operations. Towards the sustainable operations, technology transfer across the entities in HSC operations are also recommended (Santos *et al.*, 2016). One of the participants revealed that disruptions in relief chains might be due to wrong material handling and packaging technology in practice. In addition, for aftermath reconstruction projects, advanced construction technology is a solid enabler of adding a value to the economy, society and environment and to get the desired results in HSC operations (Amadei *et al.*, 2009). Also, choice of degradable materials is also to be considered for greening the HSCs (Oberhofer *et al.*, 2015).

2.1.19 Adequate equipment requirements and choice. In addition to the technology, it is important to deploy the right material and handling equipment in an HSC. Otherwise, the probability of supply chain disruptions in the system impacting the HSC performance is really high. For example, to transfer the medical supplies needs right kind of medical equipment to store and transfer. And, it has to be diligently chosen by the HSC professionals to minimize the risks of disruptions (Santos *et al.*, 2016). Also, adequate number of equipment is also important to have seamless supply in the system.

2.2 Literature review conclusions

The key enablers were identified from extant literature and finalized after consultation with HSC experts, thus accomplishing the first research objective. Furthermore, these key enablers are used as an input in the fuzzy total interpretive structural modelling (TISM) process to develop the inter-relationship and accomplish the second research objective.

3. Research methods and analysis overview

In this section, research team provides a brief overview of the research method, to include the data collection approach. To answer the second and third research questions, the research team found the fuzzy TISM technique suitable in all aspects. This technique offers greater flexibility than interpretive structural modelling (ISM) and TISM and at the same time eliminates the limitations offered by ISM. The fuzzy TISM is an advanced technique which is used by past researchers in theory building. The fuzzy TISM is a well-articulated mental model interpreting both the nodes (signifying "what") and links (signifying "how" and "why"). The mental model of the group is not well structured and loosely defined which serves as the basis for the theory building process (Sushil, 2012; Sushil, 2016; Attri, 2017). Moreover, the fuzzy TISM provides greater flexibility in terms of understanding the level of strength among the selected criteria (Khatwani *et al.*, 2015).

To gather data for building the fuzzy TISM model, the research team initially approached an HSC expert who is an ex-military officer (South African Special Forces) and was actively involved in disaster-relief operations during South Africa floods in 2011 and 2013 South Sudan crisis. Through a brainstorming session for two hours, the research team established the contextual relationship among the selected enablers. The other four HSC experts who were approached next are currently working with the Food and Agriculture Organization in South Africa, the South African Red Cross Society, United Nations Educational, Scientific and Cultural Organization and Southern Africa Trust. Through similar brainstorming sessions, data collection is done from these four experts as well. Therefore, in total, the research team developed five structural self interaction matrix

Table II.
Linguistic scales for the influence

Linguistic terms	Linguistic values
Very high influence (VH)	(0.75,1.0,1.0)
High influence (H)	(0.5,0.75,1.0)
Low influence (L)	(0.25,0.5,0.75)
Very low influence (VL)	(0,0.25,0.5)
No influence (No)	(0,0,0.25)

Enablers	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(VH)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(VH)	V(VH)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(VH)	A(H)	A(H)	A(VH)	A(VH)	A(H)	A(VH)	A(L)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(VH)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)								
E10	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Table III.
SSIM matrix of expert 1

Table IV.
SSIM matrix of expert 2

Enablers	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(VH)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(VH)	V(H)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(VH)	A(H)	A(H)	A(VH)	A(VH)	A(H)	A(VH)	A(L)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(YH)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)								
E10	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Enablers	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(VH)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(YH)	V(VH)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(H)	A(H)	A(H)	A(VH)	A(H)	A(H)	A(VH)	A(L)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(VH)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)								
E10	A(VH)	A(H)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Table V.
SSIM matrix of expert 3

Table VI.
SSIM matrix of expert 4

Enablers	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(VH)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(VH)	V(VH)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(VH)	A(H)	A(H)	A(VH)	A(VH)	A(H)	A(VH)	A(LH)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(H)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)									
E10	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(H)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Enablers	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(H)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(VH)	V(VH)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(VH)	A(H)	A(H)	A(VH)	A(VH)	A(H)	A(VH)	A(L)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(VH)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)								
E10	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Table VII.
SSIM matrix of expert 5

(SSIM) matrices (refer to annexure-Table III–VII) based on inputs from five HSC experts. Next, the research team applied the rigorous and popular fuzzy TISM modelling technique to develop the contextual inter-relationships among the selected enablers.

The steps of the fuzzy TISM are adopted from the study by Khatwani *et al.* (2015). The first step involves start of the decision-making process; the second step is the selection of an enabler; the third step is gathering responses and preparing SSIM matrix; the fourth step is the calculation of aggregated SSIM and final fuzzy reachability matrix; the fifth step is the calculation of driving power and dependence power for Matrice d' Impacts croises multiplication appliqué an classment (cross-impact matrix multiplication applied to classification) (MICMAC) analysis; the sixth step is level partition and the final step is developing defuzzified TISM digraphs. In the next stage, the research team presents the findings from the fuzzy TISM analysis and further discusses the results. Table II presents the linguistic scales for the influence.

Table III–VII presents the SSIM matrices based on expert inputs.

Based on Table III–VII, the research team further developed the aggregated SSIM matrix (refer to Table VIII).

Further, the fuzzy reachability matrix is developed and presented in Table IX.

Table IX shows the actual relationship strength of individual enablers with respect to other associated enablers. This is the main essence of this research study and draws strategic insights for humanitarian decision-makers. For proper understanding of readers, the research team emphasizes proper explanation of every relationship.

Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1) have very high influence on early warning systems of potential hazards and continuous monitoring (E2), Awareness creation on sustainable practices in HSC (E3), Speed and quality of response (E10) and Advanced technology (E18) and Adequate equipment requirements and choice (E19). It is very critical to utilize information technology for detecting weather changes in advance and communicate to the government, humanitarian agencies and local community for emergency actions. However, it must be remembered that information technology can only be exploited by using advanced technology which ultimately improves the responsiveness (speed and quality of response).

It is also found that Deployment of information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data has high influence on Strategic planning to implement sustainable practices in HSCs (E6) and Coordination of deliveries with counterparts in affected regions (E11). It is clear that planning at various stages of HSCs can only be successful with the aid of ICTs. Therefore, humanitarian actors must understand the underlying implications of these interactions and focus on building strong ICT backbone for green humanitarian operations. The above findings corroborate with the findings of previous studies such as those by Van Wassenhove (2006) and Pettit and Beresford (2009).

Early warning systems of potential hazards and continuous monitoring (E2) very strongly influence ICTs (E1), Awareness creation on sustainable practices (E3), Responsiveness (speed and quality of response) (E10), Adoption of postponement/speculation logistics strategy (E13) and Advance purchasing and pre-positioning (E14). Therefore, advance warning systems and continuous monitoring actually helps to improve responsiveness and at the same time use ICTs to gather important data and information which can be useful for developing the emergency logistics strategy and procurement strategy for aid items.

The findings also show that early warning systems of potential hazards and continuous monitoring strongly influence Strategic planning to implement sustainable practices in HSCs (E6) and Coordination of deliveries with counterparts in affected regions (E11). This means that advance warning systems and continuous monitoring helps in developing strategic planning in

Enablesrs	E19	E18	E17	E16	E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2
E1	X(VH)	X(VH)	O(No)	A(VH)	A(VH)	O(No)	O(No)	O(No)	V(H)	V(VH)	O(No)	A(H)	O(No)	V(H)	O(No)	A(H)	V(VH)	X(VH)
E2	A(VH)	A(VH)	V(L)	A(H)	A(VH)	V(VH)	V(VH)	V(L)	V(H)	V(VH)	O(No)	O(No)	V(L)	V(H)	O(No)	A(H)	V(VH)	
E3	A(VH)	A(VH)	A(H)	A(VH)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(L)	V(L)	V(H)	V(H)	V(H)	A(H)		
E4	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)			
E5	A(VH)	A(VH)	A(H)	A(H)	A(VH)	A(VH)	A(H)	A(VH)	A(L)	A(VH)	A(H)	O(No)	V(VH)	V(VH)				
E6	V(VH)	V(VH)	V(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(H)	V(H)	V(VH)	V(VH)	V(VH)	V(VH)					
E7	V(VH)	V(H)	V(H)	A(H)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	O(No)						
E8	V(H)	V(H)	V(H)	A(VH)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)	V(H)							
E9	A(H)	V(H)	A(VH)	A(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)	V(VH)								
E10	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(H)	A(VH)									
E11	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)										
E12	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)											
E13	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)	V(H)												
E14	A(VH)	A(VH)	A(VH)	A(VH)	A(VH)													
E15	A(VH)	A(VH)	A(VH)	A(VH)														
E16	V(VH)	V(VH)	V(VH)															
E17	V(VH)	V(VH)																
E18	V(H)																	

Table VIII. Aggregated SSIM matrix

Table IX. Fuzzy reachability matrix based on aggregated fuzzy SSIM matrix

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19
E1		VH	VH	No	No	H	No	No	No	VH	H	No	No	No	No	No	No	VH	VH
E2	VH		VH	No	No	H	L	No	No	VH	H	L	VH	VH	No	No	L	No	No
E3	No	No		No	H	H	H	L	L	H	H	H	H	H	No	No	No	No	No
E4	H	H	H		VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
E5	No	No	No	No		VH	VH	No	No	No	No	No	No	No	No	No	No	No	No
E6	No	No	No	No	No		VH	VH	VH	VH	H	H	VH	VH	VH	No	VH	VH	VH
E7	No	No	No	No	No	No		No	VH	VH	VH	VH	VH	VH	VH	No	H	H	VH
E8	H	No	No	No	No	No	No		H	H	H	H	H	H	H	No	H	H	H
E9	No	No	No	No	H	No	No	No		VH	VH	VH	VH	VH	VH	No	No	H	No
E10	No	No	No	No	VH	No	No	No	No		No	No	No	No	No	No	No	No	No
E11	No	No	No	No	L	No	No	No	No	VH		H	No	No	No	No	No	No	No
E12	No	No	No	No	VH	No	No	No	No	H	No		No	No	No	No	No	No	No
E13	No	No	No	No	H	No	No	No	No	VH	VH	VH		H	No	No	No	No	No
E14	No	No	No	No	VH	No	No	No	No	VH	VH	VH	No		No	No	No	No	No
E15	VH	VH	VH	No	VH	No	No	No	No	VH	VH	VH	VH	VH		No	No	No	No
E16	VH	H	VH	No	H	VH	H	VH	VH	VH	VH	VH	VH	VH	VH		VH	VH	VH
E17	No	No	H	No	H	No	No	No	VH	VH	VH	VH	VH	VH	VH	No		VH	VH
E18	VH	VH	VH	No	VH	No	No	No	No	VH	VH	VH	VH	VH	VH	No	No		H
E19	VH	VH	VH	No	VH	No	No	No	H	VH	VH	VH	VH	VH	VH	No	No	No	

the entire HSC network by minimizing uncertainties and also aids in better coordination for deliveries in crisis-affected areas. The findings are supported by the findings of previous studies such as those by Yang *et al.* (2011); Zhou *et al.* (2011) and Brown *et al.* (2014).

Awareness creation on sustainable practices in HSCs (E3) has high influence on Trust building among disaster affected people (E5), Strategic planning to implement sustainable practices in HSCs (E6), Collaborative relationships with HSC actors (E7), Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13) and Advance purchasing and pre-positioning (E14). The findings show that creating awareness helps in building trust among disaster-affected people. It aids in better planning and improves responsiveness. It also plays an important role in meeting the minimum supply quality requirements because in the past, it was seen that poor quality of supply to disaster-affected communities had actually resulted in more health-related complications. So, it is important to create awareness among HSC actors to meet minimum supply standard before selecting and supplying any kind of aids to the community. Awareness creation can also result in adoption of suitable logistics and procurement strategies to align with the goals of sustainable HSC programmes. The findings are supported by the findings of an earlier study conducted by Day *et al.* (2012).

Learning from past disasters (E4) has high influence on Deployment of information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Early warning systems of potential hazards and continuous monitoring (E2) and Awareness creation on green practices in HSC (E3).

Learning from past disasters (E4) has very high influence on Trust building among disaster affected people (E5), Strategic planning to implement sustainable practices in HSC (E6), Collaborative relationships with HSC actors (E7), Metrics to quantify sustainability benefits in an HSC (E8), Effective agreements with suppliers and service providers involved in HSC (E9), Speed and quality of response (E10), Coordination of deliveries with counterparts in affected region (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14), Logistics capability and resources (E15), Regulatory framework (E16), Availability of funds and timely payments (E17), Advanced technology (E18) and Adequate equipment requirements and choice (E19). Therefore, learning from past disaster and knowledge management is a very important enabler for sustainable HSCs. HSC actors and policymakers need to learn from past disasters and bridge the gaps for ensuring superior performance in the HSC network. The findings are supported by the findings of a previous study conducted by Van Wassenhove (2006).

Trust building among disaster affected people (E5) has very high influence on Strategic planning to implement sustainable practices in HSC (E6) and Collaborative relationships with HSC actors (E7). It is necessary to mention that trust building can actually result in reducing the sufferings of community people under crisis mode and help in successful distribution of aids as per planning and also save the lives. There will be fewer grievances generated from the local community as well as ease of operations as planned by HSC agencies. Trust building gains support from the affected community and may aid in proper HSC planning and further implementing the system in HSC network. Secondly, trust building can actually help to improve the performance of collaborative relations among HSC actors.

Strategic planning to implement sustainable practices in HSCs (E6) has very high influence on Collaborative relationships with HSC actors (E7), Metrics to quantify sustainability benefits in a HSC (E8), Effective agreements with suppliers and service providers involved in HSC (E9), Speed and quality of response (E10), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14); Logistics capability and resources (E15), Availability of funds and timely payments

(E17), Advanced technology (E18) and Adequate equipment requirements and choice (E19). It has also got high influence on Coordination of deliveries with counterparts in affected regions (E11) and Meet minimum quality requirements of supplies (E12). Therefore, strategic planning is found to be a key enabler in green HSC practices because of its ability to strongly influence multiple factors. We can conclude that without strategic planning, it is not possible to implement green HSC practices. The above findings are supported by the findings of studies such as those by Pettit and Beresford (2009) and Balcik *et al.* (2010).

Collaborative relationships with HSC actors (E7) has very strong influence on Effective agreements with suppliers and service providers involved in HSC (E9), Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14), Logistics capability and resources (E15) and Adequate equipment requirements and choice (E19). It has also got strong influence on Availability of funds and timely payments (E17) and Advanced technology (E18). It is clear that formation of collaborative relationships or strategic alliances can actually help in meeting the contract criteria and supplying goods meeting standard quality to disaster-affected regions in an effective manner. It also helps in successful adoption of advance procurement actions and improvement of logistics capability in terms of better fleet management in an economic manner. Finally, collaborative relations help in honouring the payment terms and deadlines and also providing timely technological support as and when necessary without much delay. The findings are supported by the findings of past studies such as those by Skjoett-Larsen *et al.* (2003); McLachlin and Larson (2011), Cozzolino *et al.* (2012) and Bealt *et al.* (2016).

Metrics to quantify green benefits in a HSC (E8) has strong influence on Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Effective agreements with suppliers and service providers involved in HSC (E9), Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14), Logistics capability and resources (E15), Availability of funds and timely payments (E17), Advanced technology (E18) and Adequate equipment requirements and choice (E19). Therefore, it is important to align the HSC performance with sustainability goals. The metrics should be defined in details such as levels, categories and time frames. Finally, from the measurement, it would be possible to identify the gaps and weakness in the HSC network and will be easy for HSC agencies to focus on such areas for performance improvements. The findings are supported by the findings of the studies by Schulz and Heigh (2009) and Van der Laan *et al.* (2009).

Effective agreements with suppliers and service providers involved in HSC (E9) has actually got high influence on Trust building among disaster affected people (E5) and Advanced technology (E18). Effective agreements with suppliers and service providers involved in HSC has got very high influence on Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14) and Logistics capability and resources (E15). We argue that signing contracts with suppliers and service providers basically results in better responsiveness and superior logistics performance in the entire HSC network. The finding corroborates with the findings of past studies such as those by Blecken *et al.* (2009) and Falasca and Zobel (2011).

Responsiveness (Speed and quality of response) (E10) has got very strong influence on Trust building among disaster affected people (E5). We argue that responsiveness is the key to success in sustainable HSC practices. Without speed and quality of response, it is impossible to develop trust among disaster-affected people which is important for smooth functioning of green HSC operations (Oloruntoba and Gray, 2006; Beamon and Balcik, 2008).

It is interesting to note that Coordination of deliveries with counterparts in affected regions (E11) shows strong influence on Speed and quality of response (E10) and also shows very strong influence on Meet minimum quality requirements of supplies (E12). HSC actors must effectively coordinate and provide correct and timely information to act in time, and proper coordination also helps in meeting correct supply standard of aids (Oloruntoba and Gray, 2006; Balcik *et al.*, 2010).

Meet minimum quality requirements of supplies (E12) has very high influence on Trust building among disaster affected people (E5) and high influence on Speed and quality of response (E10). It is clear that good supply standard of aids can actually improve the morale and satisfaction levels of affected people and as well becomes easier to manage the HSC operations in that region (Beamon and Balcik, 2008; Ergun *et al.*, 2010).

Adoption of postponement/speculation logistics strategy (E13) has high influence on Trust building among disaster affected people (E5) and Advance purchasing and pre-positioning (E14) and has also got very high influence on Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11) and Meet minimum quality requirements of supplies (E12). In case proper planning is done by HSC actors, then it automatically becomes easier to implement postponement/speculation strategy and advance purchasing and pre-positioning strategy. Both these strategies can actually enhance greenness in the HSC network. The argument is supported by Jahre *et al.* (2009).

Advance purchasing and pre-positioning (E14) has very high influence on Trust building among disaster affected people (E5); Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11) and Meet minimum quality requirements of supplies (E12).

It can be argued that advance purchasing actions and pre-positioning in regional warehouses can result in building trust and confidence among people, and secondly, it facilitates the speed of delivery to the affected areas and also leads to timely supply of better quality of aids. The argument is supported by past studies such as those by Beamon and Kotleba (2006) and Duran *et al.* (2013).

Logistics capability and resources (E15) has very strong influence on Deployment of information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Early warning systems of potential hazards and continuous monitoring (E2); Awareness creation on sustainable practices in HSC (E3); Trust building among disaster affected people (E5); Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11); Meet minimum quality requirements of supplies (E12); Adoption of postponement/speculation logistics strategy (E13) and Advance purchasing and pre-positioning (E14). HSC agencies must therefore focus in building resources required to strengthening logistics capability for enhancing greenness in the HSC network. The findings are supported by the findings of past studies such as those by Tomasini and Van Wassenhove (2009), Apte *et al.* (2016); and L'Hermitte *et al.* (2016).

Regulatory framework (E16) has got very strong influence on Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Awareness creation on green practices in HSC (E3); Strategic planning to implement sustainable practices in HSC (E6); Metrics to quantify sustainability benefits in a HSC (E8); Effective agreements with suppliers and service providers involved in HSC (E9); Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11); Meet minimum quality requirements of supplies (E12); Adoption of postponement/speculation logistics strategy (E13); Advance purchasing and pre-positioning (E14); Logistics capability and resources (E15); Availability of funds and timely payments (E17); Advanced technology (E18) and Adequate equipment requirements and choice (E19) and has got strong influence on Early warning systems of potential hazards and continuous monitoring (E2); Trust building among disaster affected people (E5) and Collaborative relationships with HSC actors (E7). Needless to say that regulatory framework plays a critical role in influencing sustainable HSC operations. Proper policy and guidelines on appropriate procedures can actually improve efficiency in the HSC network (Van Wassenhove, 2006; Day *et al.*, 2012).

Availability of funds and timely payments (E17) has high influence on Awareness creation on sustainable practices in HSC (E3) and Trust building among disaster affected people (E5) and has very high influence on Effective agreements with suppliers and service providers involved in HSC (E9), Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11); Meet minimum quality requirements of supplies (E12); Adoption of postponement/speculation logistics strategy (E13); Advance purchasing and pre-positioning (E14); Logistics capability and resources (E15); Advanced technology (E18) and Adequate equipment requirements and choice (E19). Therefore, it is imperative that proper management of funds and donations are critical in functioning of HSC operations in a sustainable manner (Burkart *et al.*, 2016).

Advanced technology (E18) has very high influence on Deploy information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Early warning systems of potential hazards and continuous monitoring (E2); Awareness creation on sustainable practices in HSC (E3); Trust building among disaster affected people (E5); Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11); Meet minimum quality requirements of supplies (E12); Adoption of postponement/speculation logistics strategy (E13); Advance purchasing and pre-positioning (E14) and Logistics capability and resources (E15).

Advanced technology has also got high influence on Adequate equipment requirements and choice (E19). It is not possible to sustain HSC operations effectively without the use of advanced technology such as radio-frequency identification devices (RFID) technology, tracking systems, biodegradable packaging, long-endurance remotely piloted aircraft systems, drone for supply aids and advanced medical technology (Fawcett *et al.*, 2011; Tatham *et al.*, 2017).

Adequate equipment requirements and selection (E19) is found to very strongly influence Deploy information and communication technologies (ICTs) (E1), Early warning systems of potential hazards and continuous monitoring (E2), Awareness creation (E3), Trust building among disaster affected people (E5), Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12), Adoption of postponement/speculation logistics strategy (E13), Advance purchasing and pre-positioning (E14) and Logistics capability and resources (E15).

Adequate equipment requirements and choice is also seen to strongly influence Effective agreements with suppliers and service providers involved in HSC (E9).

In addition to the technology, it is important to deploy the right material and handling equipment in an HSC. Otherwise, the probability of supply chain disruptions in the system impacting the HSC performance is really high. Also, adequate number of equipment is also important to have seamless supply in the system (Cegiela, 2006; Chang *et al.*, 2007).

The final fuzzy reachability matrix is developed and presented in Table X.

The MICMAC analysis based on fuzzy reachability matrix of Table X is shown in Figure 1. Sector I shows the autonomous variables, sector II shows the dependent variables, sector III shows the linkage variables and sector IV shows the independent variables.

(1) Autonomous variables: These variables basically have weak dependence power and weak driving power. Six variables are identified which fall under this category such as Early warning systems of potential hazards and continuous monitoring (E2),

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
E1		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E2	(0.75,1.0,1.0)		(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0.25,0.5,0.75)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E3	(0,0,0.25)	(0,0,0.25)		(0,0,0.25)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1.0)
E4	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
E5	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
E6	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
E7	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(0,0,0.25)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
E8	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(0.5,0.75,1.0)	(0.5,0.75,1.0)
E9	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(0.75,1.0,1.0)
E10	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	
E11	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.5,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E12	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)
E13	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E14	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E15	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E16	(0.75,1.0,1.0)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
E17	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
E18	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)
E19	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0.75,1.0,1.0)
Dependence power	(4.75,6.5,10.25)	(4,5.5,9)	(6,7.50,10.5)	(0,0,4.5)	(8,11.25,14)	(3.75,5.25,9)	(3.50,5,8.75)	(2.5,3.5,7.25)	(5,7,10.25)	(11.5,16.25,17.25)
Crisp value	6.96	5.97	7.84	0.61	11.04	5.77	5.52	3.96	7.29	15.52

(*continued*)

Table X. Final fuzzy reachability matrix — Z of five experts with fuzzy and crisp values of driving power and dependence of criteria

Enablers	E11	E12	E13	E14	E15	E16	E17	E18	E19	Driving power	Crisp value
E1	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(4.75,6.5,9.75)	27.67
E2	(0.5,0.75,1.0)	(0.25,0.5,0.75)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0.25,0.5,0.75)	(0,0,0.25)	(0,0,0.25)	(5.5,8,11.25)	16.87
E3	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(4.5,7,11.5)	42.68
E4	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(12.75,17.25,18)	11.80
E5	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(1.5,2,6)	3.94
E6	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(8.5,11.5,13.5)	23.40
E7	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.75,1.0,1.0)	(7,9.5,12)	21.67
E8	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0,0,0.25)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(0.5,0.75,1.0)	(5.5,8.25,12.75)	19.30
E9	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1.0)	(0,0,0.25)	(5.5,7.5,10.5)	19.94
E10	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1,5.5)	13.81
E11	(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(1.5,2.25,6.5)	15.09	
E12	(0,0,0.25)		(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(1.25,1.75,6)	14.57
E13	(0.75,1.0,1.0)	(0.75,1.0,1.0)		(0.5,0.75,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(3.25,4.5,8.25)	17.25
E14	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)		(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(3,4,7.50)	16.72
E15	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)		(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(6.75,9,11.25)	21.18
E16	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(12,16.25,17.25)	27.77
E17	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)		(0.75,1.0,1.0)	(0.75,1.0,1.0)	(7.75,10.5,12.75)	22.54
E18	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)		(0.5,0.75,1.0)	(8,10.75,12.75)	22.73
E19	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0.75,1.0,1.0)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)		(8,10.75,12.75)	22.73
Dependence power	(10,13.75,15.75)	(9.75,13.5,15.5)	(8.5,11.5,13.5)	(9,12.25,14.25)	(6.5,8.75,11.25)	(0.75,1,5.25)	(3.50,5,8.75)	(5.25,7.25,10.5)	(5.5,7.5,10.5)		
Crisp value	13.11	12.98	11.19	11.83	29.17	1.63	5.52	7.53	7.71		

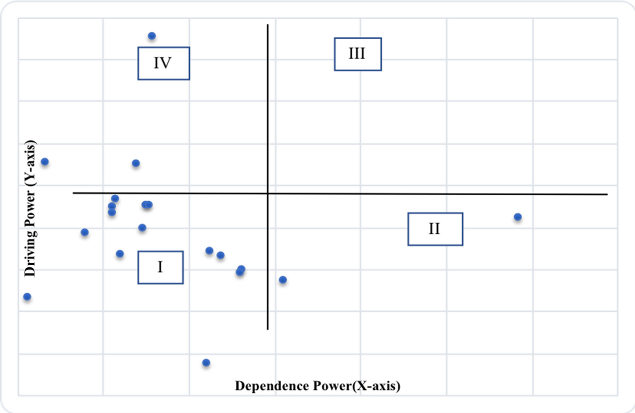

Figure 1.
MICMAC analysis

Learning from past disasters (E4), Trust building among disaster affected people (E5), Metrics to quantify sustainability benefits in a HSC (E8), Adoption of postponement/speculation logistics strategy (E13) and Advance purchasing and pre-positioning (E14).

(2) Dependent variables: These variables have strong dependence power but weak driving power. In total, three variables are identified which fall under this category such as Speed and quality of response (E10); Coordination of deliveries with counterparts in affected regions (E11) and Meet minimum quality requirements of supplies (E12).

(3) Linkage variables: The linkage variables have both strong dependence power and strong driving power. One linkage variable is found which is the Logistics capability and resources (E15).

(4) Independent (driver) variables: These variables have low dependence power but strong driving power. In total, nine driver variables are found such as Deploying information and communication technologies (ICTs), Geographic information systems (GIS), remote sensing and satellite data (E1); Awareness creation on sustainable practices in HSC (E3); Strategic planning to implement sustainable practices in HSC (E6); Collaborative relationships with HSC actors (E7); Effective agreements with suppliers and service providers involved in HSC (E9); Regulatory framework (E16); Availability of funds and timely payments (E17); Advanced technology (E18) and Adequate equipment requirements and choice (E19).

The defuzzified reachability matrix with fuzzy linguistic terms is presented in Table XI.

Next, the research team presents results of the MICMAC analysis (Figure 2) based on defuzzified reachability matrix based on Table XI. Sector I shows the autonomous variables, sector II shows the dependent variables, sector III shows the linkage variables and sector IV shows the independent variables.

(1) Autonomous variables: There are no autonomous variables.

(2) Dependent variables: These variables have strong dependence power but weak driving power. In total, five variables are found which fall under this category such as Speed and quality of response (E10), Coordination of deliveries with counterparts in affected regions (E11), Meet minimum quality requirements of supplies (E12),

Table XI. Defuzzified reachability matrix with fuzzy linguistic terms

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	Driving power
E1	1	1	1	0	1*	1	1*	1*	1*	1	1	1*	1	1*	1*	0	1*	1	1	17
E2	1	1	1	0	1*	1	1*	1*	1*	1	1	1*	1	1	1*	0	1*	1*	1*	17
E3	0	0	1	0	1	1	1	1*	1*	1	1	1	1	1	1*	0	1*	1*	1*	15
E4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
E5	0	0	0	0	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1*	14
E6	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	13
E7	1*	1*	1*	0	1*	0	1	0	1	1	1	1	1	1	1	0	1	1	1	15
E8	1	1*	1*	0	1*	0	0	1	1	1	1	1	1	1	1	0	1	1	1	15
E9	1*	1*	1*	0	1	0	0	0	1	1	1	1	1	1	1	0	0	1	1*	13
E10	0	0	0	0	1	1*	1*	0	0	1	0	0	0	0	0	0	0	0	0	4
E11	0	0	0	0	1*	0	0	0	0	1	1	1	0	0	0	0	0	0	0	4
E12	0	0	0	0	1	1*	1*	0	0	1	0	1	0	0	0	0	0	0	0	5
E13	0	0	0	0	1	1*	1*	0	0	1	1	1	1	1	0	0	0	0	0	8
E14	0	0	0	0	1	1*	1*	0	0	1	1	1	0	1	0	0	0	0	0	7
E15	1	1	1	0	1	1*	1*	0	0	1	1	1	1	1	1	0	0	1*	1*	14
E16	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
E17	1*	1*	1	0	1	1*	1*	0	1	1	1	1	1	1	1	0	1	1	1	16
E18	1	1	1	0	1	1*	1*	0	1*	1	1	1	1	1	1	0	0	1	1	15
E19	1	1	1	0	1	1	1*	0	1	1	1	1	1	1	1	0	0	0	1	14
Dependence power	11	11	12	1	18	15	16	8	13	19	17	18	15	16	14	2	10	13	14	

Note(s): *indicates transitive links

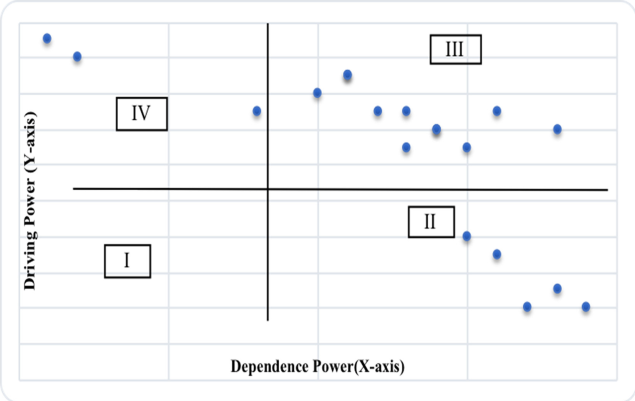

Figure 2.
MICMAC analysis

Adoption of postponement/speculation logistics strategy (E13) and Advance purchasing and pre-positioning (E14).

(3) Linkage variables: The linkage variables have both strong dependence power and strong driving power. Twelve linkage variables are identified such as Deploying information and communication technologies (ICTs), geographic information systems (GIS), remote sensing and satellite data (E1); Early warning systems of potential hazards and continuous monitoring (E2); Awareness creation on sustainable practices in HSC (E3); Trust building among disaster affected people (E5); Strategic planning to implement sustainable practices in HSC (E6); Collaborative relationships with HSC actors (E7); Metrics to quantify sustainability benefits in a HSC (E8); Effective agreements with suppliers and service providers involved in HSC (E9); Logistics capability and resources (E15); Availability of funds and timely payments (E17); Advanced Technology (E18) and Adequate equipment requirements and choice (E19).

(4) Independent (driver) variables: These variables have low dependence power but strong driving power. Two driving variables are found such as Learning from past disasters (E4) and Regulatory framework (E16).

Table XII presents the Summary of iterations of final fuzzy reachability matrix. The TISM model is presented in Figure 3 which shows the levels and hierarchy of all the enablers with respect to each other.

4. Discussion

The TISM model shows that nineteen enablers have achieved fifteen different levels. Learning from past disasters is the bottom level enabler that can provide HSC agencies involving NGOs and government agencies rich insights and new learning which can be useful in using the GHSC framework. Therefore, learning from past disasters can bridge gaps in HSC networks. The findings are supported by the findings of a previous study by Van Wassenhove (2006). Proper regulatory framework can be used as a directive to attract funding and further developing regional technological centres that will deploy advanced ICTs to provide early warnings of potential hazards and monitor it continuously to avoid massive effects on local people and also provide guidelines to mitigate risks. This will also create green awareness among local people leading to practice of proper sanitation, thus avoiding contamination of local environment. Trust building can be enhanced through

Table XII. Summary of iterations of final fuzzy reachability matrix (based on Table IX) partition

Enablers	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,5,6,7,8,9,10,11,12,13,14,15,17,18,19	1,2,4,7,8,9,15,16,17,18,19	1,2,7,8,9,15,17,18,19	XIII
2	1,2,3,5,6,7,8,9,10,11,12,13,14,15,17,18,19	1,2,4,7,8,9,15,16,17,18,19	1,2,7,8,9,15,17,18,19	XIII
3	3,5,6,7,8,9,10,11,12,13,14,15,17,18,19	1,2,3,4,7,8,9,15,16,17,18,19	3,7,8,9,15,17,18,19	XII
4	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4	4	XV
5	5,6,7,8,9,10,11,12,13,14,15,17,18,19	1,2,3,4,5,7,8,10,11,12,13,14,15,16,17,18,19	5,7,8,9,10,11,12,13,14,15,17,18,19	XI
6	6,7,8,9,10,11,12,13,14,15,17,18,19	1,23,4,5,6,10,12,13,14,15,16,17,18,19	6,10,12,13,14,15,17,18,19	X
7	1,2,3,5,7,9,10,11,12,13,14,15,17,18,19	1,2,3,4,5,6,7,10,12,13,14,15,16,17,18,19	1,2,3,5,7,10,12,13,14,15,17,18,19	VIII
8	1,2,3,5,8,9,10,11,12,13,14,15,17,18,19	1,2,3,4,5,6,8,16	1,2,3,5,8	IX
9	1,2,3,5,9,10,11,12,13,14,15,18,19	1,2,3,4,5,6,7,8,9,16,17,18,19	1,2,3,5,9,18,19	VII
10	5,6,7,10	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	5,6,7,10	I
11	5,10,11,12	1,2,3,4,5,6,7,8,9,11,13,14,15,16,17,18,19	5,11	III
12	5,6,7,10,12	1,23,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19	5,6,7,12	II
13	5,6,7,10,11,12,13,14	1,2,3,4,5,6,7,8,9,13,15,16,17,18,19	5,6,7,13	V
14	5,6,7,10,11,12,14	1,2,3,4,5,6,7,8,9,13,14,15,16,17,18,19	5,6,7,14	IV
15	1,2,3,5,6,7,10,11,12,13,14,15,18,19	1,2,3,4,5,6,7,8,9,15,16,17,18,19	1,2,3,5,6,7,15,18,19	VI
16	1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19	4,16	16	XIV
17	1,2,3,5,6,7,9,10,11,12,13,14,15,17,18,19	1,2,3,4,5,6,7,8,16,17	1,2,3,5,6,7,17	VIII
I8	1,2,3,5,6,7,9,10,11,12,13,14,15,18,19	1,2,3,4,5,6,7,8,9,15,16,17,18	1,2,3,5,6,7,9,15,18	VII
19	1,2,3,5,6,7,9,10,11,12,13,14,15,19	1,2,3,4,5,6,7,8,9,15,16,17,18,19	1,2,3,5,6,7,9,15,19	VI

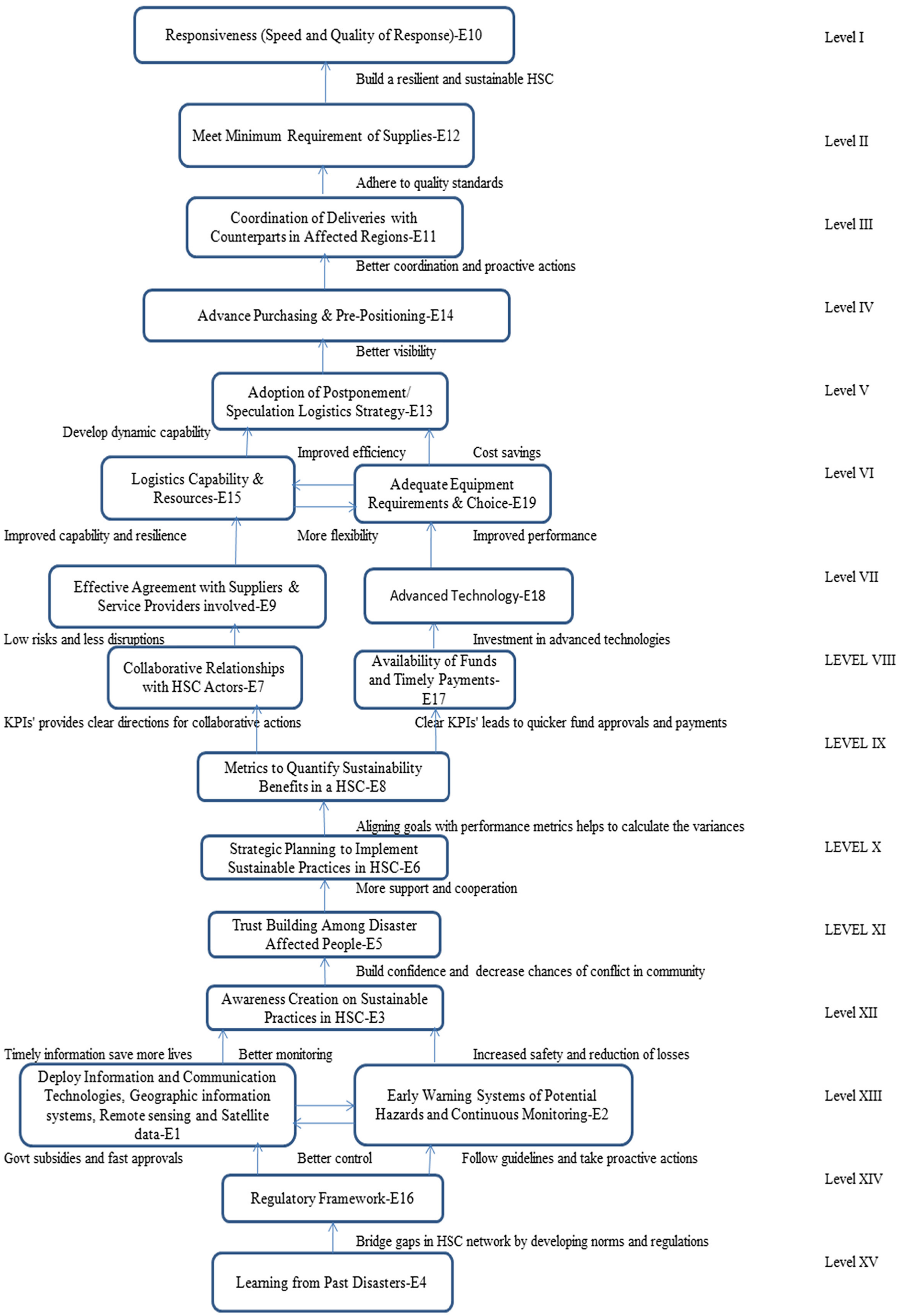

Figure 3.
TISM model

various awareness creation programmes, and agencies will find it easier to strategically plan and implement green practices. This finding is supported by the study by McLachlin and Larson (2011) where the authors emphasized on building relationships based on trust to smoothly run HSC operations. Such planning will lead to development of metrics for monitoring GHSC performance. Measuring performance can plug the gaps in an HSC, and it is essential that focus is given towards development of collaborative relationships. Making timely payments for supplies is important to avoid any supply-related crisis. Collaborative relationships can be enhanced through signing of long-term contractual agreements and organizing supply in a structured manner to ensure development of logistics capabilities. Collaborative relationships can simplify the HSC complexities and save more lives (Van Wassenhove, 2006). Logistics capabilities may involve permanent or temporary logistics hubs. However, temporary hub location is built after a disaster occurs and thus abilities to develop such logistics capabilities are critical for success or failure of disaster-relief operations (Maharjan and Hanaoka, 2019). On the other side, availability of funding can help in deploying advanced information technology and jointly both can decide adoption of a suitable green supply strategy to avoid oversupply/undersupply and wastage of perishable food and supplies to the affected areas. Advance purchasing and pre-positioning (Turkeš and Sörensen, 2019) lead to better coordination and proactive actions for resource allocation and avoiding wastage of resources. Purchase and supply play a critical role in the success of HSC operations. The findings of our study indicate that advance purchasing and supply actions and pre-positioning may lead to availability of resources at warehouses that are located at various regions. Lamenza *et al.* (2019) have recently proposed a purchasing portfolio model in HSC operations. Relief items can be categorized under supply complexity (high and low) and purchasing criticality (high and low) based on 2x2 matrix, and items will fall under one of the four categories, i.e. regular, leverage, strategic and bottleneck items. Adoption of the right strategy can be useful in meeting minimum requirements of supply in the affected areas, and finally, the research team observed that responsiveness, i.e. the speed and quality, is a very important enabler in the GHSC. The findings also indicate that learning from past disasters will help to align disaster-relief strategies with GHSC goals; deploying advanced technologies to detect early signs of disasters and green awareness creation among people will build adaptability levels, and finally, responsiveness, which is the top level enabler, ultimately improves agility in the GHSC. The study thus advances HSC literature by attending the call of past researchers (Sarkis *et al.*, 2012; Kunz and Gold, 2017; Zarei *et al.*, 2019).

5. Conclusion

Green supply chain management is the pressing call of the day (Mangla *et al.*, 2013; Mangla *et al.*, 2015; Mangla, 2019) due to the adverse impact of manufacturing operations on the environment. Therefore, green supply chain related to manufacturing companies has received more attention from the research community (Mangla *et al.*, 2013; Mangla *et al.*, 2018; Piyathanavong *et al.*, 2019; Thakur and Mangla, 2019; Mangla *et al.*, 2019). However, literature on GHSC management operations is limited. The biggest problem in front of local and state governments and various humanitarian agencies is the lack of an instrument to integrate sustainability in the traditional HSC framework. The attributes of the HSC, such as urgency and sudden onset of a crisis, makes it difficult for comprehensive planning that would match emerging demand with needed supply. The problems can be managed if we undertake a smart approach by understanding key GHSC enablers and inter-relationships amongst them and take green initiatives accordingly. The paper used a novel approach to identify and examine key enablers to green HSC. Further, the enablers were analyzed using the fuzzy TISM, and the contextual inter-relationships have been presented.

Managers must check the strength of the inter-relationships (very high, high and low) which can help in better understanding of the situation and can aid in better decision-making.

Current challenges associated with the HSC can be minimized by integrating sustainability in the entire process. It is essential that we learn from previous disasters and develop appropriate regulatory frameworks and standardized best practices. Further, ICTs should be used to gather satellite and other data and send early warnings for taking emergency actions. It is important that agencies involved in HSC management also create awareness in disaster-prone regions so that more lives can be saved and suffering can be alleviated during actual crisis situations. Moreover, it is very crucial to build trust among disaster-affected people so that HSC operations become easier. Greening of HSCs can be possible through strategic planning of green material, inventory and green logistics management. Therefore, more focus is required in this direction to build robust networks that are agile and resilient. Also, green metrics must be used to measure the performance of green HSC. The research team also highlights the importance of collaborative relationship building with HSC partners for developing capability and effective use of available resources. This also helps in adopting strategies such as postponement/speculation logistics strategies and advanced purchasing and pre-positioning strategies. Good coordination plays a key role in ensuring that deliveries reach the affected areas and helps in meeting minimum requirements for supplies. However, above all, the speed and quality of response is the top enabler in GHSC management.

5.1 Social implications

The findings of the study provide some insights for the society and people. It is important that HSC organizations learn from past disasters. Whatever mistakes have happened in the past must not be repeated again, and rather learning from such events must be used to amend practices for future disaster-relief operations. One more finding that must be highlighted is the trust building among disaster-affected people. After a disaster-related event, normally the local people become panicked and behavioural changes are observed among them. It is very important that HSC agencies operating in disaster-affected areas build trust among disaster-affected people so that they get the cooperation from the local people and relief operations become smoother. Without understanding the beliefs and further gaining faith of local people, the chances of accessing the remote parts of the area and resource allocation may not happen properly. Also, it then becomes lot easier to convince disaster-affected people for following the green practices while doing consumption of food and disposal of items.

5.2 Unique contribution, limitations and future research directions

To the best of our knowledge, this is a novel attempt to identify enablers to GHSC management. Secondly, the research team has used an advanced MCDM methodology (fuzzy TISM) to develop the contextual inter-relationships among the enablers which has not been used earlier in this direction and thus advances the GHSC literature.

The study suffers from few limitations which can be taken care in future research studies. Firstly, the sample size used in this study is small because the research team has used five HSC experts to capture data. Secondly, the data have been collected in context to African continent. Thirdly, the research team has used human judgement to develop the contextual inter-relationships. The above limitations can be eradicated by considering a larger size of sample from different countries and then comparing the model. Future research can also focus on statistical validation of the proposed model using structural equation modelling technique.

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