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A comprehensive framework for analyzing challenges in humanitarian supply chain management: A case study of the Iranian Red Crescent Society

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ABSTRACT

A Humanitarian supply chain deals with the delivery of supplies to the population of areas affected by natural disasters. One of the most important issues in Humanitarian Supply Chain Management (HSCM) is identifying and structuring different challenges and barriers in relief chains. This study is an attempt to provide a comprehensive framework for HSCM challenges in a case study of the Iranian Red Crescent Society (IRCS). We identify HSCM challenges through literature review and expert opinions and use Fuzzy Delphi Method (FDM) to select the most important challenges. Fuzzy Interpretive Structural Modeling (FISM) is then used to map the cause and effect relationships among various factors and develop a holistic picture of the main HSCM challenges. Finally, the overall framework of the HSCM challenges and the hierarchical model of the FISM are statistically verified using the Partial Least Square (PLS) method. We identify "managerial challenges" (at the category level), and "unfamiliarity of top managers with management knowledge" and "inappropriate division of labor" (at the sub-challenges level) as the root sub-challenges in this case study. Challenges not handled properly in pre-disaster stage will most likely occur more drastically in the post-disaster stage of the operations. The proposed model provides insightful guideline for increasing the effectiveness of relief efforts.

1. Introduction

Delivering the 'right supplies', at the 'right time', to the 'right place', in the 'right quantities' and to the 'right people' are the critical success factors in commercial and humanitarian supply chain management systems [1,2]. Several researchers have also pointed out the cross-learning opportunities between commercial and humanitarian sectors [2–4]. Despite these similarities, there are several differences between commercial and humanitarian supply chains. For instance, disaster relief operations are often carried out in environments with destabilized infrastructure such as limited access to roads and a lack of energy sources [5]. In contrast to the commercial sector, humanitarian organizations often have to deal with a high number of stakeholders including donors, the media, governments, and the final beneficiaries [2]. Therefore, one could argue that humanitarian efforts take place in a much more complex and challenging environment. This complexity results from a number of factors including the unpredictability of demand, suddenness of its occurrence in large amounts, time pressures, and lack of resources [2,3,5–8]. Indeed, humanitarian supply chains are always dealing with *the unknown* [2].

Multiple humanitarian supply chain management (HSCM) challenges have been identified and discussed across various studies in the literature. For instance, several studies have referred to lack of coordination as a fundamental problem in humanitarian action (B. [2,9–14], arguing that this challenge could cause numerous impacts ranging from ineffective aid distribution, to competition among actors for scarce resources, and congestion at airports and local roads [11]. In addition, problems in fundraising have been highlighted as an important challenge of HSCM [2,15,16]. That is, limited funding could drive humanitarian organizations to concentrate on immediate relief rather than making investments that would benefit the community in the long-term (B. [9,17]. Many other challenges have been discussed throughout the literature including poor information technology infrastructure, cultural differences among involved organizations, lack of clear polices, lack of

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knowledge management systems, and lack of trust between actors (B. [9, 11,16–18].

Although the subject of HSCM challenges has been debated extensively in the humanitarian operations literature, a comprehensive list of the challenges encompassing different phases of disaster relief is still needed. We have identified to major gaps in the HSCM research. First, to the best of our knowledge, none of the previous studies investigated the interrelationships between HSCM challenges from different phases of disaster management and little effort has been put into developing a holistic framework underpinning how the challenges interact. That is, the majority of studies have so far concentrated on the identification of the challenges without taking into account the possible cause and effect relationships among them. Second, previous studies like Ghasemian Sahebi, Arab, and Sadeghi Moghadam [19] and Kabra et al. [17] have not validated the relationships between HSCM challenges and left it for future studies. Therefore, the previous studies only developed a framework or a list of HSCM challenges without testing their validity, in particular, using advanced statistical methods such as PLS. However, it is important to examine the linkages and interactions between various elements in a system to understand it holistically since the whole is more than merely the sum of its parts. For instance, it can be argued that emergency response efforts consist of two interlinked phases of pre- and post-disaster response, and that these two should not be studied separately [12,20,21]. In this paper, we attempt to address these gaps in the literature and argue that improvements in the logistics and supply chain management of humanitarian operations require taking a holistic approach. This paper seeks to discover the following for the Iranian Red Crescent Society (IRCS):

- A suitable framework of the HSCM challenges with respect to different phases of disaster management, and
- The cause and effect relationships among these HSCM challenges?

The research methodology used here is a combination of Fuzzy Delphi Method (FDM), Fuzzy Interpretive Structural Modeling (FISM), and PLS. Delphi Method was developed by Dalkey and Helmer [22] for gathering data and reaching a consensus among experts on a specific real-world subject. There are applications of Delphi method in HSCM literature. For example, Richardson, de Leeuw, and Dullaert [23] used Delphi to determine a set of factors for inventory location decisions in emergencies and disasters. Sahebi, Arab, and Moghadam [24] identified 28 HSC barriers through literature review and expert interviews in a case study of the Tehran Red Crescent Society. They used fuzzy Delphi to classify a set of barriers into 9 categories and applied the Best-Worst method to analyze the importance of each barrier. Their findings identified cultural, managerial, and educational barriers as the most important ones. Singh, Gupta, and Gunasekaran [25] identified factors affecting the resilience in the humanitarian supply chain. They used Delphi to map the relationships among the identified factors, and the interpretive structural modelling to determine the structural relationships among these factors. They identifies "government support", "strategy and capacity planning", and "continuous assessment of project progress" as the main driving factors.

ISM enables individuals or groups develop a map of complex relationships and calculate an adjacency matrix to present the relationships among a set of variables [26]. ISM uses experts' practical experience and knowledge to construct a multilevel structural and hierarchical model [27]. There are numerous applications of ISM in the humanitarian supply chain. Yadav and Barve [28] applied ISM to determine the interdependency among a set of critical success factors in humanitarian supply chains and identified government policies and organizational structure as the most dominating factors through Matrice d'Impacts Croisés Multiplication Appliquée à un Classement (MICMAC) analysis. Yadav and Barve [29] applied total interpretive structural modelling for mapping the interrelation among challenges in HSCM. Their results identified the poor strategic planning and lack of investment in shelters warehouses as the dominating factors.

PLS has also been used in HSCM literature for validating the proposed models. Schniederjans, Ozpolat, and Chen [30] used PLS to examine the relationships in the conceptual model of the impact of cloud computing on collaboration and agility in HSCM. Kabra and Ramesh [31] studied the relationship between critical factors in HSCM and used PLS to analyze a set of hypotheses. They identified organizational agility and flexibility as the main factors affecting HSCM performance with the mediating role of IT utilization. Kabra, Ramesh, Akhtar, and Dash [32] studied the IT adoption in HSCM and used PLS to test the interrelationships between four constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions. They identified performance expectancy and effort expectancy as the critical factors in HSCM performance. Nezih Altay, Gunasekaran, Dubey, and Childe [33] examined the moderating effect of organizational culture on the impact of agility and resilience on HSCM performance. They used the dynamic capability view to develop the model and PLS to evaluate the research hypotheses.

In this study, 38 challenges were identified from a comprehensive review of literature, and 13 challenges were proposed following interviews with experts from the IRCS, a member of the International Federation of Red Cross and Red Crescent Societies (IFRC). A Fuzzy Delphi Method (FDM) is then used to reach a consensus on the most important and relevant humanitarian challenges. The Delphi Method (DM) is a research tool particularly well suited to new research areas and exploratory studies [34]. In contrast to the DM, the FDM uses a one-time survey approach without repetitive iterations, thus being more cost and time efficient in gathering expert opinions. In addition, expert opinions in FDM could be expressed without distortion (T. H. [35]. After selecting the most important challenges, a Fuzzy Interpretive Structural Modeling (FISM) is used to draw a conceptual picture of the challenges considering their internal dependencies. The FISM is a powerful method for developing hierarchical structure in complex systems and presenting the cause-and-effect relationships among various factors. We use linguistic variables to capture the intensity of relationships among the factors and transform them into triangular fuzzy numbers (TFNs). Finally, to our knowledge, as the first effort in HSCM literature, we have tested the validity of the framework of HSCM challenges and the hierarchical model of FISM by using PLS.

The remainder of the paper is organized as follows: Section 2 reviews the concept of HSC, disaster management cycle, managerial tasks and challenges in HSCM. Section 3 presents the methods used in this study. Section 4 discusses the research design. Section 5 introduces the problem context and the case of IRCS. In Section 6, the main HSCM challenges are identified and represented in a hierarchical structure and. The cause and effect relationships among the HSCM challenges are also investigated in this section. Finally, Section 7 concludes with the main contributions and recommendations for future studies.

2. Literature review

2.1. HSCM

HSCM deals with disasters ranging from earthquakes, droughts, famines, to a combination of several disasters occurring simultaneously [36]. According to the United Nations International Strategy for Disaster Reduction (UNISDR), a disaster is defined as "[…] a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex, long-term processes" [37]. In addition, Van Wassenhove [2] defined disaster as "a disruption that physically affects a system as a whole and threatens its priorities and goals". According to the IFRC, a disaster is "a serious disruption of the functioning of a community through widespread losses and disruption that exceed its capacity to cope using its own resources" [38]. Different types of disasters can be classified based on the source of the disaster being man-made or natural, and the warning time being slow or rapid [2,36]. Sudden-onset disasters could cause strong damages to the physical infrastructure of the area such as bridges, air fields, electricity networks, and communication infrastructure [16,36,39,40]. In this study, we are focusing on natural and sudden-onset disasters such as earthquakes and floods. Following a disaster, a relief chain is formed, the purpose of which is to provide humanitarian assistance in the form of food, water, medicine, shelter, and supplies to the areas affected by large-scale emergencies such as hurricanes, earthquakes, floods, volcanic eruption, terrorist attacks, coups, and industrial accidents [41].

The HSCM literature distinguishes among different phases of disaster relief. Accordingly, several categories have been proposed by researchers [36]. For instance, Ludema and Roos [42] differentiated between emergency relief, rehabilitation and development phases; and Safran [43] between prevention, transition, and recovery. In addition, Pettit and Beresford [44] proposed preparedness, response, and recovery; and N. Altay and Green [45] suggested mitigation, preparedness, response, and recovery. In this research, we used the framework proposed by N. Altay and Green [45]. The *mitigation* phase is defined as the application of initiatives aimed at preventing a disaster or reducing the impacts should one occur. Examples of such measures include land use controls to prevent occupation of high hazard areas, barrier construction to deflect disaster forces, and risk analysis to estimate the potential of hazards. The *preparedness* phase refers to activities related to making the community prepared for potential disasters, examples of which include maintaining and pre-positioning contingency stocks of essential supplies, threat-based public education, disaster drills to train personnel and test capabilities, and optimization of logistics and communications (N. [38,45]. Furthermore, *response* is the employment of resources and emergency procedures for the purpose of saving life, property, the environment, and the socioeconomic structure of the community. Activities such as evacuation of threatened populations, urban search and rescue, emergency medical care, and fatal management would fall under this category. Finally, *recovery* entails actions taken in the long-term in order to stabilize the community and bring back normality to the lives of the affected people, examples of which are as follows: Disaster debris cleanup, rebuilding of roads and key facilities, full restoration of lifeline services, and mental health care (N. [45].

Several studies argue that different phases of disaster relief should be perceived as a cycle connecting recovery back to the mitigation phase [20,36,43,44,46–48]. Accordingly, the recovery phase could potentially include learning elements for forthcoming emergency situations, examples of which include the installation of tsunami warning systems, or raising disaster awareness through educational programs [36,38]. Such measures are particularly important to empower communities to manage their own risks [49]. On the other hand, the implementation of a relief program should be designed in a way to facilitate the transition from relief to recovery [18,46,47]. In summary, it is imperative for humanitarian decision-makers to have a holistic picture of the disaster lifecycle when designing their programs [46,50]. As we also argue in this paper that challenges hindering disaster management across all disaster relief phases are interrelated and cannot be studied in isolation.

2.2. Challenges of HSCM

Disaster relief supply chains are unique and operate under especial circumstances that would make most commercial supply chain managers frustrated [2,4,6,51]. For instance, while the strategic goal of a commercial supply chain is to make financial returns for shareholders and delivering values to customers, the main goal of a relief chain is to save lives, reduce suffering, damages and losses [6,16,38,52,53]. There could be as many as hundreds of humanitarian organizations at the scene of a disaster at any point in time including local and international humanitarian organizations, private sector companies, governments, military, and individuals [2,46]. Accordingly, significant challenges in setting and prioritizing objectives could arise in relief operations owing to the large number of stakeholders in a relief chain, their different ideologies and religious beliefs, conflicting objectives and interests, and lack of coordination [6]; B. [2,9,46,53,54].

Moreover, challenges could arise in the case of relief chains, since demand requirements should be estimated after an evaluation of disaster characteristics. This along with zero lead time, price gouging, and unreliable transportation routes could make order fulfillment much more challenging. Additionally, local tariff and taxes on foreign aids could further increase complexity and costs [1,15]. Furthermore, timely response critical in humanitarian relief chains could be influenced by multiple factors including procurement and delivery strategies, supplier location, transportation choice, safety concerns, infrastructure, and politics [1]. Van Wassenhove [2] argues that the pressure of time in a relief chain does not have to deal with money, but rather a question of life and death. In addition, not all disaster situations share the same characteristics and each emergency situation could be unique based on a number of factors ranging from location, number of affected people, regional temperature, to the nature of the disaster [1,20,52].

Considering the many challenges and complexities facing humanitarian organization, it is not surprising that the topic has been the focus of extensive debate in the literature. For example, Balcik, Beamon, Krejci, Muramatsu, & Ramirez [9] focused on pre- and post-disaster relief operations and discussed a number of coordination challenges in disaster relief. They identified diversity of actors, donor expectations and funding structures, competition for funding, unpredictability, resource scarcity/oversupply, and coordination costs as the main drivers of coordination challenges. They also argued that differences in geographical, cultural, and organizational policies may create additional challenges (B. [9]. Although they discussed coordination challenges and mechanisms extensively, they spoke mostly from a theoretical perspective and their study lacked a practical application of these mechanisms in a case study. In addition, Jahre and Jensen [10] discussed the need for coordination during both preparedness and response. The purpose of their research was to provide a theoretically based evaluation of the cluster system, and to explore the challenges and tradeoffs in achieving several types of coordination in the cluster system. More recently, Kabra, Ramesh, & Arshinder [17] identified coordination challenges of HSCM and grouped them into categories of management, technological, cultural, people, and organizational challenges. They used the analytic hierarchy process (AHP) to prioritize these barriers and concluded that lack of top management commitment and lack of policies for coordination were the major challenges to coordination. However, they did not consider the cause-and-effect relationships between the challenges.

In addition, Kovács and Spens [36] used the case study of Ghana to identify challenges of HSCM concentrating on different types of disaster, phases of disaster, and types of humanitarian organizations. They identified a number of challenges including the involvement of different organizations in the response, customs clearance procedures, a lack of access to training, lack of standards and indicators, the absence of clear mandates and legislation, low recognition of logistics, and inadequate infrastructure. They concluded that lack of coordination is the most important challenge. The significant role of coordination has also been emphasized in other studies of the literature including Jahre and Jensen [10]; and Van Wassenhove [2].

Furthermore, Mohebifar, Tabibi, and Asefzadeh [55] discuss that there are several managerial and structural challenges and barriers of HSCM in Iran. They argued that in Iran, different organizations such as the Ministry of Health, Treatment and Medical Education, IRCS, Medical Society Mobilization, and the military are responsible for training and dispatching health, treatment, and services to disaster-struck areas, and each one considers itself as the leader of providing services in emergency situations. Due to the absence of a centralized integrated management and planning system, and lack of coordination, they often act in parallel to one another and their activities may overlap and interfere. Therefore, there is little possibility to plan and execute a unified program to encounter emergencies. Stauffer, Pedraza Martinez, Yan, and Van Wassenhove [56] addressed the challenge of maintaining the rest of the world development programs and simultaneously responding to a mega disaster. They showed how network asset flows in international humanitarian organizations supply change in disasters. While most previous researches assume independent asset flows, the authors concluded that when disaster flow increases, hub-to-hub asset flows in the rest of the world are reduced and other asset flows increase. Rodríguez-Espíndola, Albores, & Brewster [47] proposed a model for the challenge of balancing the human and material resources from multiple organizations with the objectives of maximizing the level of provided service and cost minimizing to avoid an excess of actors involved in the real-life situations resulting from independent decision-making. Table 1 summarized the identified challenges of HSCM extracted from the literature review and interviews with panelists.

3. Methods

3.1. Fuzzy Delphi Method (FDM)

The DM developed by Dalkey and Helmer [22] is a technique used to obtain the most reliable consensus among a group of experts. Consensus is obtained through consultations of up to ten rounds of questioning which provides experts with important information such as averages and deviation from the previous rounds, thus enabling them to modify their opinions (Kardaras, Karakostas, & Mamakou, 2013). As such, the DM has several advantages over similar decision-making methods including the avoidance of a direct confrontation between the participants [34], and the opportunity for experts to receive feedback reports. In addition, several variants of the method have been tailored to specific problem types and outcome goals. For example, one variant that has received widespread attention is the *ranking-type* Delphi, used to develop group consensus about the relative importance of issues. Forecasting and issue identification/prioritization represent another variant of the method [72].

However, the traditional DM has some disadvantages, such as low convergence of expert's opinions, high execution cost, and the possibility of filtering out particular experts' opinions [73]. Accordingly, Murray, Pipino, and Gigch [74] proposed the FDM to tackle the weaknesses of the traditional Delphi, where membership degree is used to establish the membership function of each participant. Further, Ishikawa et al. [75] introduced the fuzzy theory into the DM and developed max–min and fuzzy integration algorithms to predict the prevalence of computers in the future. However, the limitation of this approach is that it is only applicable to predicting time series data. T. H. Hsu and Yang [35] used triangular fuzzy numbers (TFNs) to encompass experts' opinions and establish an FDM. More specifically, the max and min values of experts' opinions were taken as the two extreme points of TFNs, and a geometric mean was taken as the membership degree of the TFNs to derive the statistical unbiased effect and avoid the impact of extreme values. As a result, the experts are not required to modify their opinions in this approach. Many methods have been proposed to combine the experts' opinions such as the mean, median, max, min, and mixed operators [76]. Since the experts' consensus in multi-criteria decision-making methods such as the FDM or the Fuzzy Analytic Hierarchy Process (FAHP) is typically calculated using the geometric mean (T. H. [35,73,77], we used a geometric mean for aggregating the experts' opinions in this paper. The advantages of the FDM applied in this study over the traditional DM are summarized below:

a. While the traditional DM requires multiple investigations to obtain the consistency of opinions, the FDM requires only one investigation, thus being more efficient in terms of time and cost.
b. In the traditional DM, experts are required and forced to modify their extreme opinions, so that they meet the mean value of all the opinions. Otherwise, they might be excluded from the investigation. Therefore, there is a possibility that some useful information is overlooked. However, it is argued that the FDM respects the original opinions of all the experts and modifies extreme values by eliminating the max and min values of triangular opinions [34,78].
c. The FDM helps experts express their optimistic, pessimistic, and realistic opinions. This process will enhance the accuracy of realistic opinions compared to the traditional Delphi, where experts are asked to express their opinions only by one linguistic variable or number.
d. Unlike other group decision-making techniques such as face-to-face meetings or nominal groups which require physical proximity of the group members, the participants in a Delphi study can be physically dispersed and do not need to meet in person [79].

In this research, we sought to explore, refine, and combine the opinions of a group of experts to establish a judgment. Considering the above-mentioned advantages and other benefits of the FDM such as anonymity, we believe that this approach is a good fit with the purpose of this study. Therefore, the FDM proposed by T. H. Hsu and Yang [35] was adopted in this paper.

3.2. Fuzzy interpretive structural modeling (FISM)

The philosophical basis for the development of the Interpretive Structural Modeling (ISM) was proposed by Warfield [27]. The method provides a fundamental understanding of complex situations and puts together a course of action for solving a problem. It enables individuals or groups to develop a map of complex relationships and to calculate an adjacency matrix to present relationships among a set of variables [26]. In other words, the basic idea of ISM is to decompose a complicated system into several sub-elements by using experts' practical experience and knowledge in order to construct a multilevel structural and hierarchical model. The ISM can therefore be used for identifying and analyzing relationships among specific variables, which define a problem or an issue [27]. In summary, the main benefit of the ISM methodology is that it transforms unclear and poorly articulated models of systems into visible, well-defined, and structured models (Sage, 1977).

Despite the benefits, the ISM has a number of drawbacks as well. First, there is the subjective bias of the person who is judging the variables, as the relations among variables always depend on that person's knowledge and familiarity with the case, related industry, and business operations. Second, ISM does not provide any weighting associated with the variables [80]. Third, it is not always reasonable to use the binary relation among elements [81]. Finally, the traditional ISM does not consider the severity of relationships between elements and experts are therefore forced to decide whether a relationship exists or not (binary decision). This might in turn lead to unwanted relations between the elements in the final results.

Accordingly, we integrated fuzzy set theory [82] into the ISM in order to overcome the aforementioned drawbacks. A fuzzy relation with a degree of strength often exists and the adoption of the fuzzy set theory can provide a system with no sharp boundaries. Fuzzy set theory is helpful in dealing with the vagueness of human thought and expression in making decisions. In particular, fuzzy set theory presents a useful method for converting linguistic terms into TFNs. Therefore, the principle behind the FISM is to change the traditional binary value into a fuzzy binary relation and to provide interviewees with the opportunity to express the strength of the relationship among the elements. This approach has previously been used in several research studies including the works of A. I. Lee and Lin [83]; Mitamura and Ohuchi [84]; Parameshwaran et al. [26]; Raghuvanshi and Kumar [85]; Tazaki and Amagasa [81]; and Tseng [86].

3.3. PLS-SEM methodology

Structural equation modeling (SEM) is a popular multi-variate data

Table 1
Challenges extracted from the HSCM literature and expert interviews.

Challenge	Pre-disaster		Post-disaster		Source
	Mitigation	Preparedness	Response	Recovery	
Unpredictability of demand (characteristics and requirements of the affected population, and disaster unpredictability in terms of timing, location, type, and size)		×	×		[6,57,58]
Short (zero) lead times for a wide variety of supplies, and urgency of response (zero delivery time)			×		[6,36,59]
Infrastructure and limited accessibility to disaster-struck locations			×	×	[36,58,60]
Sanctions against Iran and constraints for cooperation (e.g. with other humanitarian organizations)	×	×	×	×	Interview with experts
Disasters exacerbated by integrity of several disasters (e.g. an earthquake leading to the destruction of a dam and causing a flood)			×		[58,61]
Burn-out and turnover of rescuers and humanitarian volunteers, and shortage of skillful people			×		(B [9,57,60].
Unpleasant and challenging working conditions for rescuers (security and safety of rescuers during relief operations)			×	×	[36,58]
Poor usage of technology (e.g. GPS, robots, early warning systems, and information technologies)	×	×	×	×	[6,36,57,58]
Lack of enough funding to finance disaster management	×	×	×	×	[62]
Lack of appropriate transportation facilities (e.g. helicopters and trucks)			×	×	[6,36,57,58]
Inadequate infrastructure (e.g. ports, airports, and roads)			×	×	[6,36,57,58]
Lack of relief goods (e.g. medicine, food, and water)			×	×	[6,36,57,58]
Low-quality or inappropriate aid products			×	×	[58]
Lack of energy sources (e.g. electricity, and gas)			×	×	[58]
Lack of top management commitment to enhancing coordination	×	×	×	×	[63,64]
Unaccountability over organizational performance	×	×	×	×	[1,59,65]
Unfamiliarity of top managers with management knowledge	×	×	×	×	[36]
Regional focus and assignment of supportive resources	×	×	×	×	Interview with experts
Presence of new and inexperienced actors (humanitarian organizations)			×	×	(B [9,61].
Lack of cooperation and coordination among involved actors	×	×	×	×	[36,58]
Lack of trust among humanitarian organizations	×	×	×	×	[59,64]
Armed conflicts and political crises			×	×	[36]
Problems related to customs clearance (e.g. time-consuming process, and tariff and taxes on foreign aids)		×	×	×	[36,58]
Dependence on political decision to declare state of emergency		×	×		[36,66]
Absence of legislation and supportive rules	×	×	×	×	[36]
The extent of disparity in organizations' power and resources		×	×	×	[66,67]
Threatening the value of being independent from other agencies or being a sovereign entity	×	×	×	×	[67]
Lack of knowledge and familiarity with other organizations	×	×	×	×	[36]
Cultural differences among involved organizations			×		(B [9,57,67].
Differences in operational procedures among involved organizations (e.g. procedures, standards, and techniques)	×	×	×	×	[9,57,67]
Weak educational system and mock disaster drills		×	×		Interview with experts
Unstable managerial positions in humanitarian organizations	×	×			Interview with experts
Unethical issues (e.g. theft and corruption)			×	×	[58]
Emigration from affected areas			×	×	[36]
Improper training for affected people in post-disaster relief		×	×	×	Interview with experts
Media and information sharing obstacles, competition to visibility and media coverage			×	×	[57–59,68]
Communication barriers (e.g. different languages and cultures)			×	×	(B [9,67,69].
Inadequate efforts for raising awareness among people (e.g. about humanitarian activities, humanitarian organizations, and fundraising)	×	×	×	×	Interview with experts
Spread of rumors causing fear among people			×		Interview with experts
Bureaucratic organizational structures		×	×		[57,58]
Facility location problems (including warehousing problems and prepositioning items out of the reach of the potential demolishing impact of a disaster, while at the same time close enough to the disaster zone as to deliver aid quickly and effectively)		×	×		[1,36,58]
Inadequate training for rescuers		×	×		[60,62,70,71]
Weak monitoring on humanitarian operations		×	×	×	Interview with experts
Lack of integrated systems for gathering aids	×	×	×	×	Interview with experts
Inappropriate division of labor	×	×	×	×	Interview with experts
Lack of cost management systems	×	×	×	×	Interview with experts
Unaccountability to donors for spending money	×	×	×	×	[58]
Allocation of costs, benefits, and risks among involved parties			×	×	[59]
Unfair assignment of deliveries to affected people			×	×	Interview with experts
Lack of standards and indicators for performance management	×	×	×	×	[36,60]
Purchasing difficulties in post-disaster relief (e.g. Time-consuming process, price gouging			×	×	Interview with experts

analysis method which is used for testing theoretically supported linear and additive causal models [87]. Two types of variables exist in SEM: (1) endogenous or dependent variable; and (2) exogenous or independent variable with the usage of observable or non-observable (latent) classification. A typical SEM analysis involves two sub-models; the inner model or the structural model that clarifies the relationships between the latent variables, and the outer model (known as a measurement model) that specifies the relationships between the latent variables and also their observed indicators. A conceptual model is needed for SEM analysis to show the relationship between the constructs (latent variables) based on strong logic and theoretical background [88]. We created a conceptual model for this purpose using the ISM. The SEM is then applied to test its validity. We use partial least squares (PLS) as opposed to LISREL or other covariance based-methods of SEM because it allows for including formative items in the analyses and it requires smaller sample sizes than LISREL (W. W. [89]. The software utilized for the analysis is Smart PLS, version 3.

4. Research design

Data gathering tools in this research were literature review, structured interviews, and questionnaires. The first tool was used to uncover an initial set of HSCM challenges. Since the keywords 'challenges' and 'barriers' are used interchangeably in the literature, we searched for both in our review of the literature. We utilized the FDM to explore and select challenges of HSCM across a diverse sample of RCSs in Iran. The choice of a specific design and the methodological characteristics of a Delphi process are dependent on the research question defined by the analyst and vary significantly among studies [90]. The Delphi approach presented here was devised in a structured format to assess a list of pre-defined challenges extracted from the literature review, and to explore new challenges not included in the initial list by interviewing the experts. The overall research framework is presented in Fig. 1. An important and critical part of Delphi is selection of the panelists, since it directly affects the quality of the results generated (C.-C. [91]. The panelists' selection criteria are normally derived based on the purpose of the study. Although the criteria have been vague in some cases and there is no general consensus in the literature with regards to which criteria should be used [90], four requirements related to expertise have been outlined by Adler and Ziglio [92]; namely experience and knowledge with the issues under investigation, willingness and capacity to participate, sufficient time to participate, and effective communication skills. In this research, the experts' selection criteria were in accordance with those proposed by Adler and Ziglio [92].

The minimum number of participants needed to ensure effective group performance in the DM is dependent on the study design. The Delphi group does not depend on statistical power but rather on group dynamics to arrive at a consensus among experts. Therefore, representativeness of the sample is evaluated based on the qualities of panelists, not the size of the panel [90]. The literature recommends the inclusion of 10–30 experts for sampling on a Delphi panel [93,94]. However, a heterogeneous panel (i.e. a panel that includes members with the same degree of expertise but from different social or professional scales) would require fewer experts. Altogether, research team contacted 30 low, middle, and high-level managers with more than 10 years of experience in the field of humanitarian operations from the IRCS. The low, middle, and high labels are chosen according to the position of the expert in the IRCS. Low is used for *supervisors*; middle is used for *department heads*; and high is used for *directors*. After explaining the subject of the research, procedures, and the amount of time required for the study, 26 experts accepted our invitation to join our research panel. The Managerial level, experience, and academic degree of each expert is shown in Table 2. All 26 experts were interviewed in the first phase, and 20 experts completed the survey questionnaire in the second phase. The response rates in the first and second phases were approximately 86% and 66% respectively.

The use of FDM in this study consisted two of phases. In the first phase, the panelists were interviewed to verify the appropriateness and relevance of the challenges identified through the literature review, to acquire their viewpoints, and to propose further challenges not included in the initial list. Next, all responses were consolidated into a single list and challenges having the same definitions were omitted according to the advice by Ref. [95]. In the second phase, the FDM questionnaire was distributed to experts to identify which challenges were considered as the most important and relevant for the Iranian context. In other words, we asked experts to specify the importance of the challenges generated from the literature review and the first round of FDM in a 1–9 scale ranging from 'very unimportant' to 'very important'.

Another method applied in this research was the FISM which was used for structuring and interpreting interrelationships among the challenges. The FISM was applied to understand the interactions and cause-and-effect relationships among the challenges. Therefore, in the third stage, a paired comparison questionnaire was distributed to the experts and they were asked to identify the relationships among each pair of challenges by using the linguistic variables listed in Table 3. They were also asked to express the reasons why they thought those relationships were present. Based on the results of the FISM, a hierarchical structure was constructed. Next, a clustering method called the cross-impact matrix multiplication applied to classification (MICMAC) was applied to divide the challenges into the four clusters of *autonomous*, *dependent*, *linkage*, and *independent*. This approach provides us with a better understanding of the driving and dependence power of each challenge [80].

Finally, we used the survey method to test our conceptual model obtained via interpretive logic by using ISM. Based on the results from FDM, a survey questionnaire was designed and distributed among RCS branches in Iran. These experts are mostly the humanitarians from RCSs branches and other related organizations who are involved at least in one of disaster management phases. The resulting respondents sample held positions such as President, Vice President, Director, Head, Manager, Supervisor, and Specialist. The resulting dataset had 75 responses out of 600 possible responses, which satisfies the sampling rules proposed by Wynne W. Chin [96]. That is, based on a rule of thumb of 10 cases per predictor, a research can choose the sample size 10 times of the largest number of structural equations or measurement equations in the conceptual model.

4.1. Step 1: developing an initial list of HSCM challenges

In the first stage, we identified and preselected relevant challenges by reviewing the literature and conducting interviews with experts. In this study, we made use of a structured interview with managers in order to propose any further and relevant challenges in IRCS which were not taken into consideration in the literature review.

4.2. Step 2: refining the extended list of HSCM challenges

In the second stage, the FDM was applied to select the most important challenges from the initial list compiled in the previous stage. The steps of FDM are as follows:

a. Experts' opinions are collected from a questionnaire and the experts are asked to provide their most pessimistic (minimum), most optimistic (maximum), and most possible values for the importance of each challenge in the challenges set S in a range of one to 10. A score is denoted as a TFN $\tilde{a}_i^k = (l_i^k, m_i^k, u_i^k)$, $i \in S$ where l_i^k is the pessimistic, u_i^k is the optimistic, and m_i^k is the most possible index of challenge i rated by expert k.
b. Calculate the aggregate triangular fuzzy value for each challenge ($\tilde{a}_i$), which is obtained as follows:

$$\tilde{a}_i = (l_i, m_i, u_i) \tag{1}$$

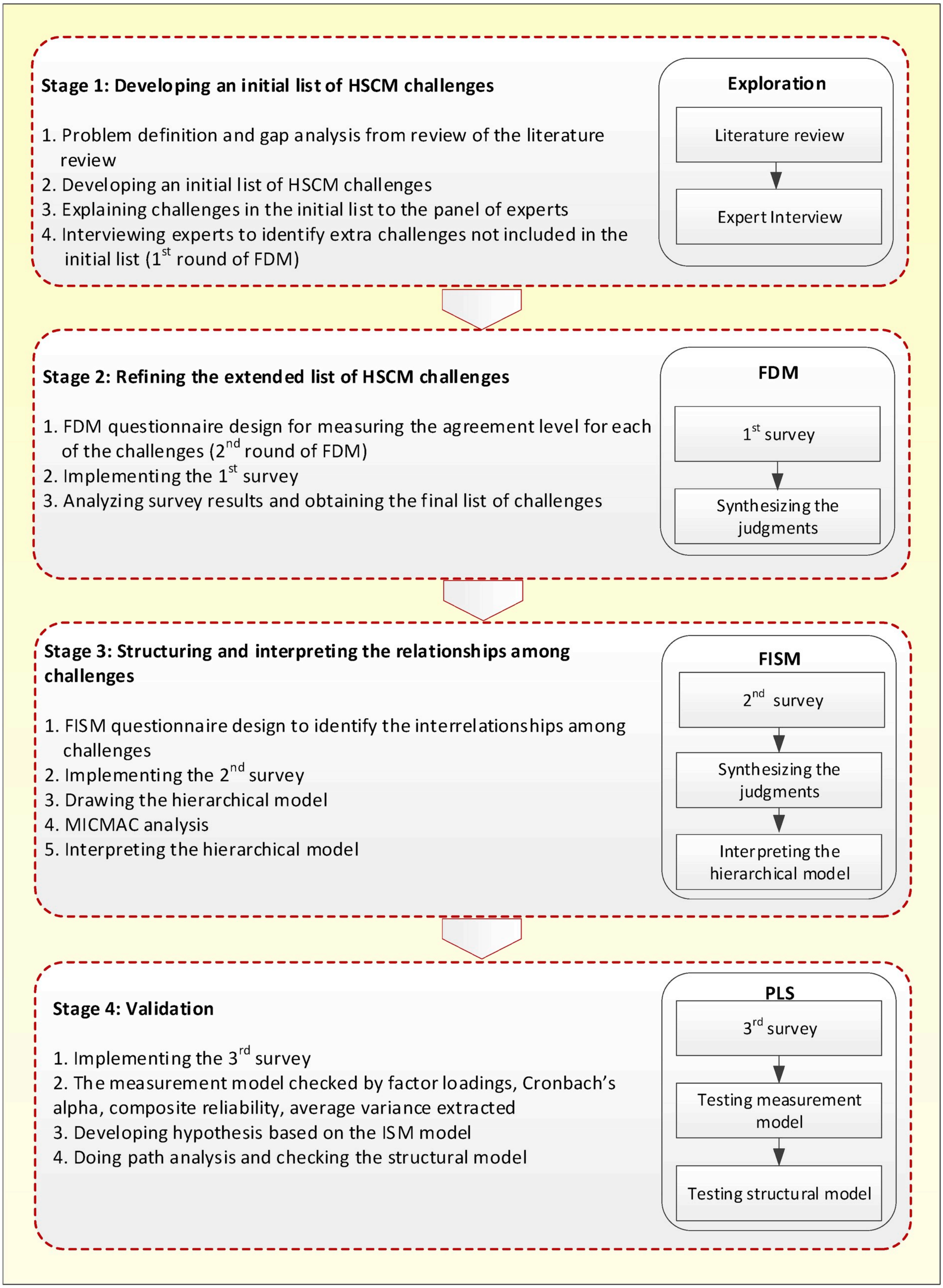

Fig. 1. Proposed framework.

Table 2
Profile of experts.

No. of experts	Academic degree	Work Experience (years)	Managerial Level
E1	Bachelor	11	Low
E2	Bachelor	12	Low
E3	Master	10	Low
E4	Bachelor	13	Low
E5	Master	10	Low
E6	Master	11	Low
E7	Master	12	Low
E8	Master	13	Low
E9	Bachelor	11	Low
E10	Bachelor	15	Low
E11	Bachelor	14	Low
E12	Bachelor	13	Low
E13	Bachelor	12	Low
E14	Bachelor	13	Low
E15	Master	14	Low
E16	Master	16	Middle
E17	PhD	12	Middle
E18	Master	14	Middle
E19	Master	15	Middle
E20	PhD	13	Middle
E21	Master	17	Middle
E22	Master	18	High
E23	Master	25	High
E24	Master	20	High
E25	Master	22	High
E26	Master	24	High

Table 3
TFN for FISM [86].

Linguistic term	Linguistic value
Absolutely related (AR)	(0.75,1,1)
Strongly related (SR)	(0.5,0.75,1)
Fairly related (FR)	(0.25,0.5,0.75)
Low related (LR)	(0,0.25,0.5)
Unrelated (UR)	(0,0,0.25)

$$l_i = \min\left(l_i^k\right) \tag{2}$$

$$m_i = \left(\prod_{k=1}^{n} m_i^k\right)^{1/n} \tag{3}$$

$$u_i = \max\left(u_i^k\right) \tag{4}$$

As it can be seen, l_i is the bottom of all experts' most pessimistic value for challenges *i*, m_i is the geometric mean of all experts' most possible value for challenges *i*, and u_i is the ceiling of all experts' most optimistic value for challenge *i*.

c. In the final step, the geometric mean m_i of each challenge's TFN is used to denote the consensus of the expert group, so that the impact of extreme values could be avoided. For the threshold value *r*, the selection criteria are as follows:

$$\begin{aligned} &if\ a_i \geq r, \ \text{the challenge is accepted.} \\ &if\ a_i < r, \ \text{the challenge is rejected.} \end{aligned}$$

We note that the threshold value, *r,* is set as different values in previous studies. In reviewing these studies, we find that in general, there are four approaches for identifying the threshold values. These approaches which we name as the *strict*, *mean*, *moderate*, and *conservative* approaches are explained below:

d. *Strict* approach; in which the threshold value is set high -a little lower than the ceiling value of the scale employed-is used for selecting the most important factors. For example, Kuo and Chen [73] set the threshold value at 8 on a scale of 1–10 based on the 80/20 rule.
e. *Mean* approach; in which the mean of the used scale or the mean of the opinions is considered as the threshold value. An example of this approach is the study conducted by Ma et al. [77] who set the threshold value at 2.5 on a scale of 1–5.
f. *Moderate* approach; this approach is between the *mean* and the *strict* approaches. For instance, Y.-L. Hsu, Lee, and Kreng [97] had set the threshold value at 7 on a scale of 1–10.
g. *Conservative* approach; in which a value lower than the mean is employed as the threshold value to maintain most factors. An example of the use of this approach could be found in Wang, Yeo, and Ng [98].

It could be argued that the *strict*, *moderate*, *mean*, and *conservative* approaches are located on a spectrum and as we move from the *strict* to the *conservative* approach, the mouth of the funnel becomes larger and more factors will pass through. In this research, there was a consensus among the experts to set the threshold value at 6. Therefore, we are applying the *moderate* approach, ensuring that a suitable number of challenges will be selected for further analysis.

4.3. Step 3: structuring and interpreting the relationship among challenges

The FISM was employed in the third stage to identify and structure the interactions among HSCM challenges. The steps involved in this stage are summarized as below:

a. Identifying and selecting the most relevant challenges; based on the result of stage two, the selected challenges are defined as C_i, $i = 1, 2, 3, \ldots, n$. The presence of a relationship between a pair of challenges is obtained through a questionnaire containing the linguistic variables of 'absolutely related', 'strongly related', 'fairly related', 'low related', and 'unrelated' [86]. The TFNs in Table 2 are used to express the strength of the relationships between the challenges.
b. Aggregating experts' opinions; different approaches exist for aggregating experts' opinions. For instance, Warfield [27] proposed the *mode* of opinions in the traditional ISM; meaning that if the there is consensus among experts that a relationship holds between two factors, the value of the relationship between those factors would be set to 1. Otherwise, the factors are not considered as being related and the value would be set to 0. Consequently, the most frequent value (i.e. 0 or 1) of the comparisons among factors is called the *mode*, which gives us the adjacency or relation matrix [99]. In fact, the *mode* method is the same as a simple arithmetic mean of binary values with a threshold of 0.5; meaning that if the arithmetic mean of the opinions is higher than the threshold, a relationship exists between the relevant factors. In addition, A. H. I. Lee, Wang, and Lin [100] used a geometric mean to aggregate the opinions of experts. Several methods have been proposed for aggregation in the FISM, including a geometric mean approach proposed by A. I. Lee and Lin [83] and a fuzzy arithmetic method employed by Tseng [86]. In this study, we decided to apply a geometric mean approach, since it is capable of satisfying unanimity and homogeneity conditions in synthesizing pairwise comparison matrices [101].

If the relationship from c_i to c_j is represented by a TFN $\tilde{x}_{ij}^k = (l_{ij}^k, m_{ij}^k, u_{ij}^k)$, aggregation of opinions for *n* experts would be calculated as follows:

$$\tilde{x}_{ij} = \left(l_{ij}, m_{ij}, u_{ij}\right) = \left(\left(\prod_{k=1}^{n} l_{ij}^k\right)^{1/n}, \left(\prod_{k=1}^{n} m_{ij}^k\right)^{1/n}, \left(\prod_{k=1}^{n} u_{ij}^k\right)^{1/n}\right) \tag{5}$$

where $\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is the integrated TFN, and l_{ij}, m_{ij}, and u_{ij} represent the overall average ratings of the minimum, the most possible, and maximum values of linguistic judgments of experts regarding the relationship between c_i and c_j.

c. Defuzzifying the fuzzy numbers; several methods could be used to achieve this transformation e.g. means of maxima, centroid method, and the a-cut method. Because of its compliance with monotony, x-translation, x-scaling, continuity, computational efficiency, and simplicity criteria [102], the centroid method or center of gravity (CG) was employed in this study to defuzzify the fuzzy numbers of the aggregated TFNs, as follows:

$$\pi_{ij} = \frac{l_{ij} + m_{ij} + u_{ij}}{3} \tag{6}$$

d. Establishing the relation matrix representing the relationships among the challenges; let π_{ij} and π_{ji} be the relation between ith and jth challenges. This relationship between any two criteria can be from c_i to c_j, from c_j to c_i, in both directions, or c_i and c_j could be unrelated. Considering the threshold value t, the selection criteria are:

$$\begin{aligned} &f\ \pi_{ij} \geq t \rightarrow \pi_{ij} = 1 \\ &f\ \pi_{ij} < t \rightarrow \pi_{ij} = 0 \end{aligned} \tag{7}$$

$$A = \begin{pmatrix} 0 & \pi_{12} & \cdots & \pi_{1n} \\ \pi_{21} & 0 & \cdots & \pi_{2n} \\ \vdots & \vdots & 0 & \vdots \\ \pi_{m1} & \pi_{m2} & \cdots & 0 \end{pmatrix}, \ i = 1,2,\ldots,m\ ,\ j = 1,2,\ldots,n \tag{8}$$

where π_{ij} denotes the relationship between the ith row and jth column challenge.

As discussed in the FDM section, different threshold values could be considered given different approaches. As noted earlier, we applied a *moderate* approach to identify the threshold value for the FISM and set it to 0.6 regarding the TFNs (see Table 2).

e. Developing the final reachability matrix; the initial reachability matrix M is calculated by adding A from the previous step to the identity matrix I. The matrix M will then be checked for transitivity.

$$M = A + I \tag{9}$$

The transitivity of the contextual relation means that if challenge c_i is related to c_j, and c_j is related to c_k, then c_i is necessarily related to c_k. Next, the final reachability matrix is obtained by increasing the power of the initial reachability matrix until the following condition is satisfied, which is under the operators of the Boolean multiplication and addition (i.e. $1 \times 0 = 0 \times 1 = 0, 1 + 0 = 0 + 1 = 1, 1 \times 1 = 1 + 1 = 1$):

$$M^* = M^k = M^{k+1} \quad k > 1 \tag{10}$$

Meaning that the procedure of raising the power of M will stop when it arrives to a convergence and that is when all the transitivity relations are considered. The Boolean multiplication rules employed for obtaining the final reachability matrix by binary relations is completely compatible with the *composition* operation for fuzzy structural modeling proposed by Tazaki and Amagasa [81].

f. Level partitioning; the reachability and antecedent sets for each challenge are found from the final reachability matrix. The reachability set for a particular challenge consists of the challenge itself and other challenges, which it may help achieve. The antecedent set consists of the challenge itself and other challenges, which may help in achieving it. Subsequently, the intersection of these sets is derived for all the challenges. The challenge for which the reachability and the intersection sets are the same is given the top level in the ISM hierarchy, which would not help achieve any other challenges above their own level. After identification of the top-level element, it is discarded from the other remaining challenges. This iteration is continued until the level of each challenge is identified. The identified levels would then be used to build a digraph.

g. Drawing the digraph; having identified levels of the elements, the relationship between them is drawn using arrows indicating the direction of relations based on the final reachability matrix.

h. Interpreting the digraph; in order to interpret the structural model more easily, it is advisable to clarify the interpretation of the links among the elements. For instance, we can derive a deeper understanding by interpreting the relationship as: 'In what way A should/will help achieve B' [103,104].

4.4. Step 4: clustering the main challenges

The objective of the MICMAC analysis is to analyze the driving power and the dependence power of each challenge. Kannan and Haq [80] classify the attributes into four clusters: *Autonomous*, *dependent*, *linkage*, and *driver/independent*.

- The *autonomous* cluster represent attributes with weak driving power and weak dependence.
- The *dependent* cluster represent attributes with weak driving power and strong dependence.
- The *linkage* cluster represent attributes with driving power and strong dependence.
- The *driver/independent* cluster represent attributes with strong driving power and weak dependence.

Based on this categorization, an attribute with a very strong driving power called the key variable falls into the cluster of independent or linkage attributes.

5. The Iranian Red Crescent Society (IRCS)

According to a recent report published by The World Bank (2014), disasters are increasing worldwide with more devastating effects than ever before. The year 2011 saw the largest economic losses yet due to natural disasters, estimated at US$370 billion worldwide. Disasters in 2010 also claimed significantly more lives, with nearly 304,000 killed—the highest number since 1976. While the absolute number of disasters around the world has almost doubled since the 1980s, the average number of natural disasters in the Middle East and North Africa (MENA) region has almost tripled over the same period. More specifically, disasters in MENA have affected more than 40 million people over the past three decades and have cost their economies close to US$20 billion. During the last five years alone, more than 120 disasters have caused an average of US$1 billion per year in damages and losses. It is argued that the synergy of natural disasters, rapid urbanization, water scarcity, and climate change have emerged as serious challenges for policy and planning in the MENA region. The most frequent disasters in the region are floods, earthquakes, storms, and droughts; with floods being the most recurrent and accounting for 53% of the total number of disasters. Earthquakes account for 24% of the total, and storms and droughts account for approximately 10% [49]. The situation is unfortunately expected to exacerbate in the future owing to the effects of climate change [36].

In the MENA region, Iran is considered as one of the most disaster-prone countries [49]. Located on the world dry belt, 60% of Iran is covered with mountains and the remaining part is desert and arid lands. Among the 40 different types of natural disasters observable in different parts of the world, 31 types have been identified in Iran. Major natural disasters include storms, floods, droughts, landslides, desertification, deforestation, and frequent serious earthquakes [105]. Being part of the Alp-Himalaya orogenic belt, Iran is subject to numerous and often strong earthquakes, causing huge economic and social impacts [48,49,105]. During the past 40 years, natural disasters in Iran have cost the lives of more than 105,000 people and affected over 43,000,000. Earthquakes alone account for over 95% of the death tolls and 50% of the total damages; with floods accounting for over 30% of the damages (http://www.emdat.be/). It is argued in a report from Unisdr [48] that no area of this territory has been impervious to earthquake waves and disasters in general. Situated on a number of major faults, several Iranian cities including the capital of Iran are susceptible to high magnitude earthquakes [106]. Therefore, the analysis of HSCM challenges for Iran is considered an important and relevant topic.

Humanitarian organizations take different forms from supranational aid agencies such as UN agencies to governmental and non-governmental organizations. Different humanitarian organizations concentrate on different types of disasters. For example, while the International Committee of the Red Cross (ICRC) responds to man-made political and armed conflicts, the IFRC is focused on disaster relief in (mostly) sudden-onset natural disasters [36]. The IFRC is the world's largest volunteer-based humanitarian network and its work focuses on four core areas: Promoting humanitarian values, disaster response, disaster preparedness, and health and community care [107]. It carries out relief operations to assist victims of disasters, and combines this with development work to strengthen the capacities of its member National Red Cross and Red Crescent Societies worldwide [107]. The IFRC's principal strength is the unique network of National Societies which covers almost every country in the world [108]. Formed in 1922 and being an active member of the IFRC, the IRCS is a relief, rescue, and medical aid organization in Iran, responsible for planning and preparing to respond to disaster, and rendering rescue and relief services to disaster-affected people. The IRCS acts before, during, and after disasters, and is by far the most important partner in disaster management in Iran [48].

6. Results

6.1. The FDM results

During the first stage of the study, an initial list of 38 challenges was developed from a comprehensive literature review. Next, face-to-face interviews were arranged with experts and following these interviews, 13 extra challenges were proposed (see Table 1). As seen in Table 3, we classified these challenges based on different phases of disaster relief management. As such, eight categories were defined as follows: Environmental, aid workers, resources, managerial, inter-organizational, affected people, organizational, and communication. 'Environmental' challenges refer to those directly led by disaster itself, its uncertainty and uncontrollable environmental factors such as sanctions. 'Aid workers' refers to the challenges related to the working conditions of rescuers. The 'resources' category deals with challenges related to the required material, and physical resources. In addition, some challenges are derived directly from the top management of the humanitarian organization, which we referred to as the 'managerial' category in this research. Another group of challenges such as those related to coordination problems and conflicts among involved organizations were classified as 'inter-organizational'. Moreover, some challenges are derived from the demand side, which we referred to as' affected people'. 'Communication' challenges refer to those caused by communication problems between humanitarian organizations and affected people. Finally, we defined 'organizational' challenges to consider those derived from internal planning, organizing, and controlling process. The respondents also suggested that several similar challenges be combined. For instance, 'warehousing location', and 'prepositioning location problems' were two distinct challenges identified but were rephrased into one named 'facility location problems' based on the suggestions of the respondents. The challenges formulated in this study are neither event-specific nor region-specific. While the challenges identified here are country based, they could not be considered independent of the events and/or disasters because our experts have drawn on their lifetime experience from various disasters when formulating these challenges.

Following the development of the initial list challenges, the FDM process begins. As noted earlier in Section 3, the experts were asked in the second stage to further pare down the initial list of challenges generated in stage 1 by assigning three numbers (TFNs) to each challenge. As such, the aggregated triangular fuzzy scores of the challenges are shown in Table 4. The feedback provided by the respondents indicated that several challenges needed to be dropped. In total, 44 challenges were dropped and only 8 were approved to remain in our final list of HSCM challenges ($\pi_{ij} \succ 6$); the two of which obtaining the highest consensus were 'lack of cooperation and coordination among involved actors' and 'inappropriate division of labor'.

It is obvious that as the threshold value is increased, and the selection approach becomes *strict*er, a smaller number of challenges would ultimately be selected. In this study, a *moderate* approach was taken, and the threshold value was set at 6. After using the TFNs and the linguistic judgment of the panelists, we defuzzified the aggregated TFNs into crisp values by using the CG method.

6.2. FISM survey result

The FISM was executed at two levels: categories and sub-categories (sub-challenges). The FISM at main level (eight categories of challenges) was designed to propose a conceptual model which could be further tested by SEM. The FISM at sub-categories or sub-challenges was designed for several reasons. First, modeling the main categories of the challenges may not reveal much about the interrelationships and cause and effect relationships between the sub-challenges. Second, the cause and effect relationships may follow a different pattern which would be in conflict with the pattern provided by the higher level model. For example, according to the FISM at higher level, the hierarchical model might show that managerial challenges influence organizational challenges, while one of the organizational challenges (e.g., lack of standards and indicators for performance management) could lead to a managerial challenge like accountability. Therefore, analysis at both levels will provide helpful insights which make this dual analysis necessary. Another important aspect of the analysis is considering the interrelationships among challenges in different phases of disaster management. In addition, some of the challenges are relevant to different phases and it is not possible to isolate them in one phase. Threshold value of 0.6 was used to determine whether any pair of challenges were related. If the crisped value between a pair of challenges in the integrated relation matrix, i.e. *c1* and *c2*, is higher than the threshold value 0.6, *c2* is deemed reachable from *c1* and we let $\pi_{12} = 1$.

6.2.1. FISM of main categories of challenges

Based on the FDM results, eight main categories of the challenges are defined. First FISM was conducted to investigate the cause and effect relationships between these categories. The initial reachability matrix is reached by applying Eqs. (5)–(9) and is shown in Table 5. The final reachability matrix is formed considering the transitivity rule. That is, if a challenge *A* leads to *B*, and *B* leads to *C*; then, *A* leads to *C*. as is shown in Tables 6 and 11 new relations were developed based on this rule.

The reachability matrix obtained above was partitioned into different levels (the level partitioning step). The reachability and antecedent sets for each challenge were obtained from the final reachability matrix. After the first iteration, the challenges forming level *I* are discarded, and the iteration procedure continues with the remaining challenges. The analysis revealed six levels in the main challenges after five iterations. Following level partitioning, a hierarchical model of HSCM main challenges was developed as shown in Fig. 2.

6.2.2. FISM of sub-challenges

Based on the results from FDM, eight challenges were selected by using the moderate approach. One could choose different approach and thus having more or less sub-challenges for further analysis, but we took

Table 4
FDM survey results.

Category	Sub-challenges	Score	Decision in different approaches			
			Strict	Moderate	Mean	Conservative
Environmental	Unpredictability of demand (characteristics and requirements of the affected population, and disaster unpredictability in terms of timing, location, type, and size)	5.25	reject	reject	reject	accept
	Short (zero) lead times for a wide variety of supplies, and urgency of response (zero delivery time)	5.00	reject	reject	reject	accept
	Infrastructure and limited accessibility to disaster-struck locations	5.16	reject	reject	reject	accept
	Sanctions against Iran and constraints for cooperation (e.g. with other humanitarian organizations)	4.66	reject	reject	reject	accept
	Disasters exacerbated by integrity of several disasters (e.g. an earthquake leading to the destruction of a dam and causing a flood)	5.44	reject	reject	reject	accept
Aid workers	Burn-out and turnover of rescuers and humanitarian volunteers, and shortage of skillful people	5.07	reject	reject	reject	accept
	Unpleasant and challenging working conditions for rescuers (security and safety of rescuers during relief operations)	5.78	reject	reject	accept	accept
	Inadequate training for rescuers	5.68	reject	reject	accept	accept
	Presence of new and inexperienced actors (humanitarian organizations)	4.46	reject	reject	reject	accept
Resources	Poor usage of technology (e.g. GPS, robots, early warning systems, and information technologies)	5.28	reject	reject	reject	accept
	Lack of enough funding to finance disaster management	6.33	reject	accept	accept	accept
	Lack of appropriate transportation facilities (e.g. helicopters and trucks)	5.59	reject	reject	accept	accept
	Inadequate infrastructure (e.g. ports, airports, and roads)	5.26	reject	reject	reject	accept
	Lack of relief goods (e.g. medicine, food, and water)	5.84	reject	reject	accept	accept
	Low-quality or inappropriate aid products	5.72	reject	reject	accept	accept
	Lack of energy sources (e.g. electricity, and gas)	5.46	reject	reject	reject	accept
Managerial	Lack of top management commitment to enhancing coordination	5.82	reject	reject	accept	accept
	Unaccountability over organizational performance	6.25	reject	accept	accept	accept
	Unstable managerial positions in humanitarian organizations	5.84	reject	reject	accept	accept
	Lack of governance principles and familiarity of top managers with management knowledge	6.11	reject	accept	accept	accept
	Regional focus and assignment of resources	5.39	reject	reject	reject	accept
Inter-organizational	Lack of cooperation and coordination among involved actors (including difficulties in enforcing others to adhere to procedures and standards)	6.54	reject	accept	accept	accept
	Lack of trust among humanitarian organizations	5.06	reject	reject	reject	accept
	Armed conflicts and political crises	4.82	reject	reject	reject	accept
	Problems related to customs clearance (e.g. time-consuming process, and tariff and taxes on foreign aids)	4.92	reject	reject	reject	accept
	Dependence on political decisions to declare state of emergency	4.32	reject	reject	reject	accept
	Absence of legislation and supportive rules	5.52	reject	reject	accept	accept
	The extent of disparity in organizations' power and resources	5.10	reject	reject	reject	accept
	Inappropriate division of labor	6.50	reject	accept	accept	accept
	Threatening the value of being independent from other agencies or being a sovereign entity	4.53	reject	reject	reject	accept
	Lack of knowledge and familiarity with other organizations	4.37	reject	reject	reject	accept
	Cultural differences among involved organizations	4.18	reject	reject	reject	accept
	Differences in operational procedures among involved organizations (e.g., procedures, standards, and techniques)	5.10	reject	reject	reject	accept
	Weak educational system and mock disaster drills	5.78	reject	reject	accept	accept
Affected people	Unethical issues (e.g. theft, corruption, etc.)	6.04	reject	accept	accept	accept
	Emigration from affected areas	4.82	reject	reject	reject	accept
	Lack of basic knowledge for affected people in post-disaster relief	5.67	reject	reject	accept	accept
Communication	Media and information sharing obstacles, competition to visibility and media coverage	4.69	reject	reject	reject	accept
	Communication barriers (e.g. different languages and cultures)	4.99	reject	reject	reject	accept
	Inadequate efforts for raising awareness among people (e.g. about humanitarian activities, humanitarian organizations, and fundraising)	4.75	reject	reject	reject	accept
	Spread of rumors causing fear among people	5.98	reject	reject	accept	accept
Organizational	Bureaucratic organizational structures	5.11	reject	reject	reject	accept
	Facility location problems (including warehousing problems and prepositioning items out of the reach of the potential demolishing impact of a disaster, while at the same time close enough to the disaster zone as to deliver aid quickly and effectively)	5.39	reject	reject	reject	accept
	Weak monitoring on humanitarian operations	6.22	reject	accept	accept	accept
	Lack of integrated systems for gathering aids	5.04	reject	reject	reject	accept
	Lack of cost management systems	5.44	reject	reject	reject	accept
	Purchasing difficulties in post-disaster relief (e.g. time-consuming process, and price gouging)	5.47	reject	reject	reject	accept
	Unaccountability to donors for spending money	5.79	reject	reject	accept	accept
	Unfair assignment of deliveries to affected people	6.25	reject	accept	accept	accept
	Allocation of costs, benefits, and risks among involved parties	5.17	reject	reject	reject	accept
	Lack of standards and indicators for performance management (difficulty of performance measurement)	5.80	reject	reject	accept	accept
	Number of accepted challenges		**0**	**8**	**21**	**51**

this based on the comments and feedbacks from the experts. The initial reachability matrix is reached by applying Eqs. (5)–(9) and is shown in Table 7. As an example, we see that 'lack of cooperation and coordination among involves actors' leads to 'unfair assignment of deliveries to affected people'. For instance, lots of aid might be sent to an affected area due to the lack of coordination between humanitarian organizations and honors, while other areas might receive inadequate goods and services.

Next, the final reachability matrix is formed considering the transitivity rule (see Table 8). As is shown, 13 new relations were developed based on the transitivity rule. Therefore, 34 relations are present in the final reachability matrix in total.

The reachability matrix obtained above was partitioned into different levels (the level partitioning step) similar to the operations for

Table 5
Initial reachability matrix of main challenges.

Main challenges		C1	C2	C3	C4	C5	C6	C7	C8
C1	Environmental	1	1	0	0	0	1	0	0
C2	Aid workers	0	1	0	0	0	1	1	0
C3	Resources	0	0	1	0	0	0	0	1
C4	Managerial	0	1	1	1	0	0	0	1
C5	Inter-organizational	0	0	0	0	1	1	0	0
C6	Affected people	0	0	0	0	0	1	0	0
C7	Communication	0	0	0	0	1	1	1	0
C8	Organizational	0	1	0	0	1	1	0	1

the main challenges. Following level partitioning, a hierarchical model of HSCM challenges was developed as shown in Fig. 3.

6.3. MICMAC analysis

Decision-makers need to be aware of the relative importance of the various challenges of HSCM. In the final reachability matrix shown in Tables 6 and 8, the driving and dependence power of each challenge is presented. Accordingly, the challenges were classified into the four clusters of *autonomous*, *dependent*, *linkage*, and *driver* based on their driving and dependence power. The results of the MICMAC analysis on the main challenges and sub-challenges is shown in Figs. 4 and 5,

Table 6
Final reachability matrix of main challenges.

Main challenges		C1	C2	C3	C4	C5	C6	C7	C8	Driving power
C1	Environmental	1	1	0	0	1*	1	1*	0	5
C2	Air workers	0	1	0	0	1*	1	1	0	4
C3	Resources	0	1*	1	0	1*	1*	1*	1	6
C4	Managerial	0	1	1	1	1*	1*	1*	1	7
C5	Inter-organizational	0	0	0	0	1	1	0	0	2
C6	Affected people	0	0	0	0	0	1	0	0	1
C7	Communication	0	0	0	0	1	1	1	0	3
C8	Organizational	0	1*	0	0	1	1	1*	1	5
Dependence power		1	5	2	1	7	8	6	3	

Note: 1* represents a relation obtained from the transitivity rule.

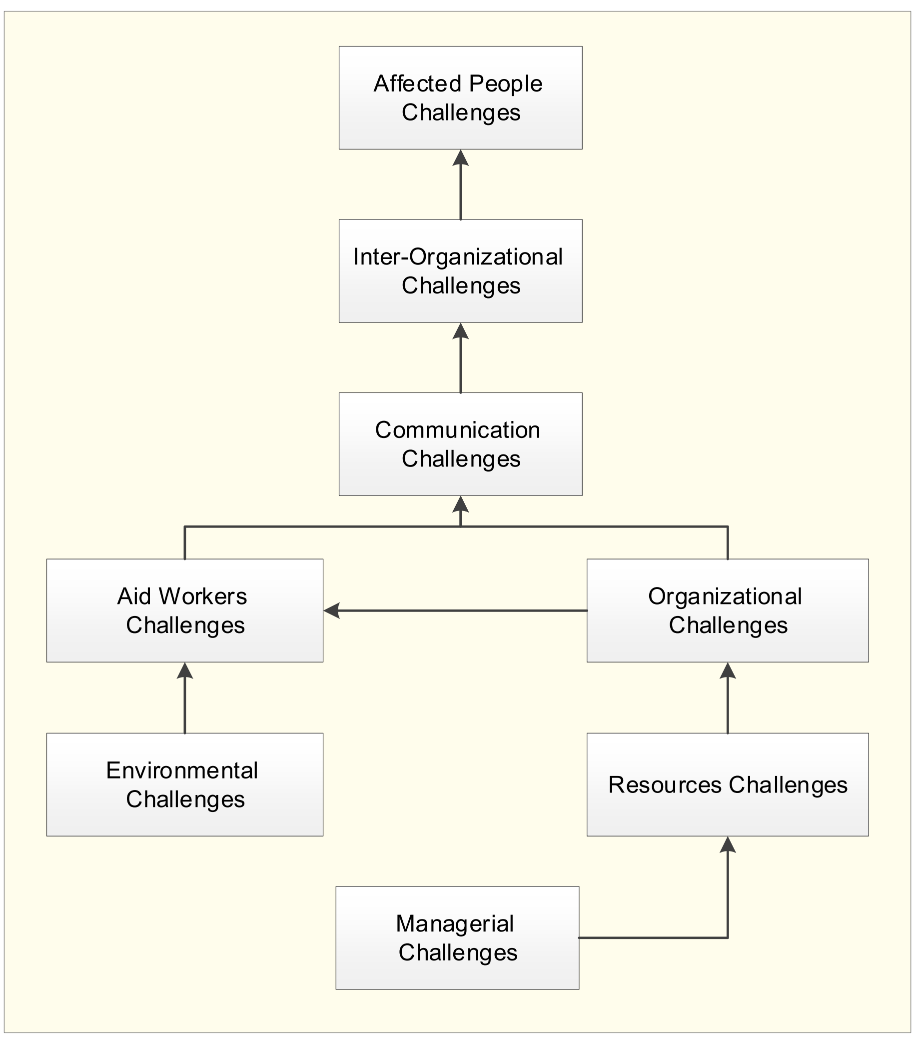

Fig. 2. The FISM model of hierarchical HSCM main challenges.

Table 7
Initial reachability matrix of sub-challenges.

Sub-challenges		C1	C2	C3	C4	C5	C6	C7	C8
C1	Lack of enough funding to finance disaster management	1	0	0	1	0	1	0	0
C2	Unaccountability over organizational performance	0	1	0	0	0	0	0	1
C3	Unfamiliarity of top managers with management knowledge	0	1	1	1	0	0	0	0
C4	Lack of cooperation and coordination	1	0	0	1	1	0	0	1
C5	Unethical issues (e.g. theft, corruption, etc.)	0	0	0	0	1	0	0	0
C6	Weak monitoring on humanitarian operations	0	1	0	0	1	1	0	0
C7	Inappropriate division of labor	0	0	0	1	0	1	1	1
C8	Unfair assignment of deliveries to affected people	0	0	0	0	0	0	0	1

respectively.

According to the results of the MICMAC analysis on sub-challenges, it is apparent that four challenges have weak dependence and strong driving power. These challenges should be interpreted as the most driving challenges [109]. Additionally, four challenges have weak driving power and strong dependence power, thus mapping to the *dependent* cluster. That is, to overcome challenges located in this cluster, there is a need to focus on their root causes. Furthermore, neither challenge was found to have strong driving and dependence power to be classified in the *linkage* cluster, nor to have weak driving and dependence power to map in autonomous cluster. Interestingly, the most *driving challenges* i.e. 'Unfamiliarity of top managers with management knowledge' and 'inappropriate division of labor' are modeled as the root challenges of the FISM hierarchical model (see Fig. 3). Thus, the drivers' sector could be considered as the root challenges which is completely in agreement with the result of the FISM hierarchical model and therefore validates it. In a similar manner, the MICMAC analysis for the main challenges (eight categories) can be interpreted. As it is shown in Fig. 4, Environmental, Resources, Managerial, and Organizational challenges are the driving challenges and the remaining challenges are the dependent ones. The Managerial challenges have the highest driving power, followed by the Resources challenges. Challenges related to Affected People are the most dependent challenges. In the next section, the validation of the FISM models is discussed.

6.4. Model validation

Model validation of the FISM is needed to generate confidence in the model. As such, we considered validation of the ISM model in terms of the several criteria. First, in this research, a comprehensive review of the literature was conducted to identify the most relevant challenges in HSCM, followed by a set of interviews with experts to confirm their relevance and check the content validity of the model. Second, we checked the validity of the framework of the identified challenges and the FISM hierarchical model by using advanced statistical methods. In this study, we used Smart PLS 3.0, which relies on PLS method to validate hypothesized model (see Fig. 2). To this end, we analyze reliability and validity of the measurement model. Then, we analyze the structural model.

6.4.1. Measurement model

We assess the reliability and validity of the constructs to ensure the appropriateness of the measurement model. The main challenges are the constructs in this study since they are measured by their respective sub-challenges. Before conducting these analyses, we performed a factor analysis for all constructs. One variable, E1, has factor loading 0.361, and was removed because of its low factor loading (far below 0.5) [110]. After removing E1, the factor loading of all variables were calculated again and are shown in Table 9. Most of the loadings are above 0.7 and some are between 0.5 and 0.7. This means all items loaded strongly in their respective constructs; hence, providing strong evidence of convergent validity. Convergent validity denotes the degree to which items (here sub-challenges) of a construct (here main challenges) should converge [111].

In addition to factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) have been used to check convergent validity and constructs' reliability. For Cronbach's alpha, typically a threshold of 0.6–0.7, for CR a minimum value of 0.6, and for AVE a minimum of 0.5 is required [112], which are all met and exceeded in this research (see Table 10).

6.4.2. Structural model

In order to assess the cause and effect relationships in the ISM hierarchical model, structural model and path analysis are considered. Based on the FISM hierarchical model and the initial reachability matrix at the category level (constructs level) of challenges, 14 direct relationships are identified and the following set of hypothesis is proposed:

H1. the challenges of are affected people influenced by the challenges of aid workers.

H2. the challenges of communications are influenced by the challenges of aid workers.

H3. the challenges of aid workers are influenced by environmental challenges.

H4. the challenges of aid workers are influenced by managerial challenges.

H5. the organizational challenges are influenced by the managerial challenges.

H6. the challenges of resources are influenced by managerial

Table 8
Final reachability matrix of sub-challenges.

Key challenges		C1	C2	C3	C4	C5	C6	C7	C8	Driving power
C1	Lack of enough funding to finance disaster management	1	1*	0	1	1*	1	0	1*	6
C2	Unaccountability over organizational performance	0	1	0	0	0	0	0	1	2
C3	Unfamiliarity of top managers with management knowledge	1*	1	1	1	1*	1*	0	1*	7
C4	Lack of cooperation and coordination	1	1*	0	1	1	1*	0	1	6
C5	Unethical issues (e.g. theft, corruption, etc.)	0	0	0	0	1	0	0	0	1
C6	Weak monitoring on humanitarian operations	0	1	0	0	1	1	0	1*	4
C7	Inappropriate division of labor	1*	1*	0	1	1*	1	1	1	7
C8	Unfair assignment of deliveries to affected people	0	0	0	0	0	0	0	1	1
Dependence power		4	6	1	4	6	5	1	7	

Note: 1* represents a relation obtained from the transitivity rule.

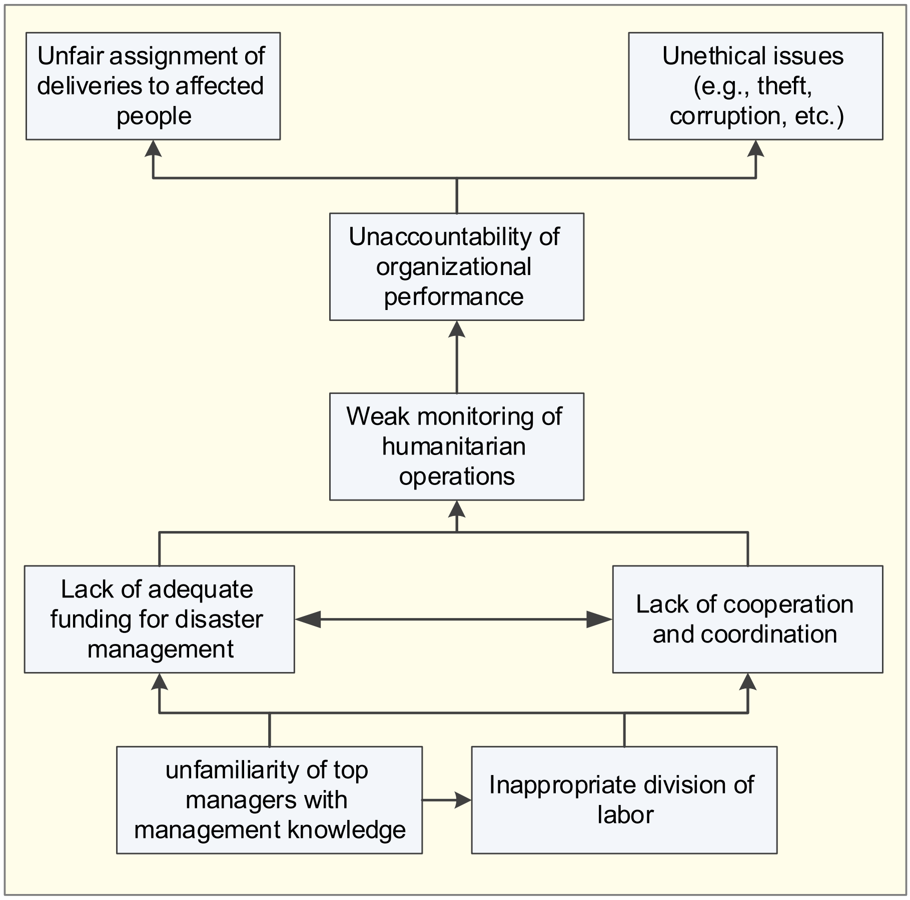

Fig. 3. The FISM model of hierarchical HSCM sub-challenges.

challenges.

H7. the challenges of affected people are influenced by the challenges of communication.

H8. the inter-organizational challenges are influenced by the challenges of communication.

H9. the challenges of affected people are influenced by the inter-organizational challenges.

H10. the challenges of aid workers are influenced by the organizational challenges.

H11. the challenges of affected people are influenced by the organizational challenges.

H12. the inter-organizational challenges are influenced by the organizational challenges.

H13. the challenges of affected people are influenced by the challenges of resources.

H14. the organizational challenges are influenced by the challenges of resources.

Each of the paths represents one hypothesis and by doing path analysis, each hypothesis is tested statistically. For evaluating the path coefficients, bootstrapping technique with 1000 resamples with replacement was used. Using a two-tailed *t*-test with a significance level of 5%, the path coefficient will be significant if the t-statistics is larger than 1.96. The results showed three hypothesizes are rejected and nine are accepted (see Table 11). Therefore, most of the identified relationships from the FISM methodology, has been found to be significant with the t-statistic and only three of the relationships are rejected since they are not statistically significant at 95% confidence level. Since in the ISM hierarchical model of sub-challenges, no construct or a latent variable is defined, it is not common to test the validity of such models by PLS.

7. Discussion

In this section, first, we discuss the results from the FDM and FISM. Then, the results from PLS-SEM are discussed. According to Table 3, by using FDM eight challenges were identified as the most important ones: 1) lack of enough funding to finance disaster management, 2) unaccountability over organizational performance, 3) unfamiliarity of top managers with management knowledge, 4) lack of cooperation and coordination, 5) unethical issues (e.g. theft, corruption, etc.), 6) weak monitoring on recovery operations, 7) inappropriate division of labor, and 8) unfair assignment of deliveries to affected people with the score of 6.33, 6.25, 6.11, 6.54, 6.04, 6.22, 6.5, and 6.25 out of 10 respectively. These results inform us that managers need to consider various kinds of challenges to improve the performance of the HSC. This statement is in agreement with Kabra et al. Kabra et al. [17] who found five categories of challenges in HSC including managerial, people, organizational, technological, and cultural barriers. Further, similar to Ghasemian Sahebi et al. [24]; collaboration and coordination are among the most important challenges.

This study uncovered a six-tiered structure of main challenges (eight categories) and five-tiered hierarchical structure of the sub-challenges encountered during humanitarian efforts that impede disaster relief. As shown in Figs. 2 and 3, the challenges within and across tiers are related, with the direction of relationships represented horizontally (intra-level relationship) and vertically (inter-level relationship) using arrows. According to Fig. 2, the challenges related to the affected people

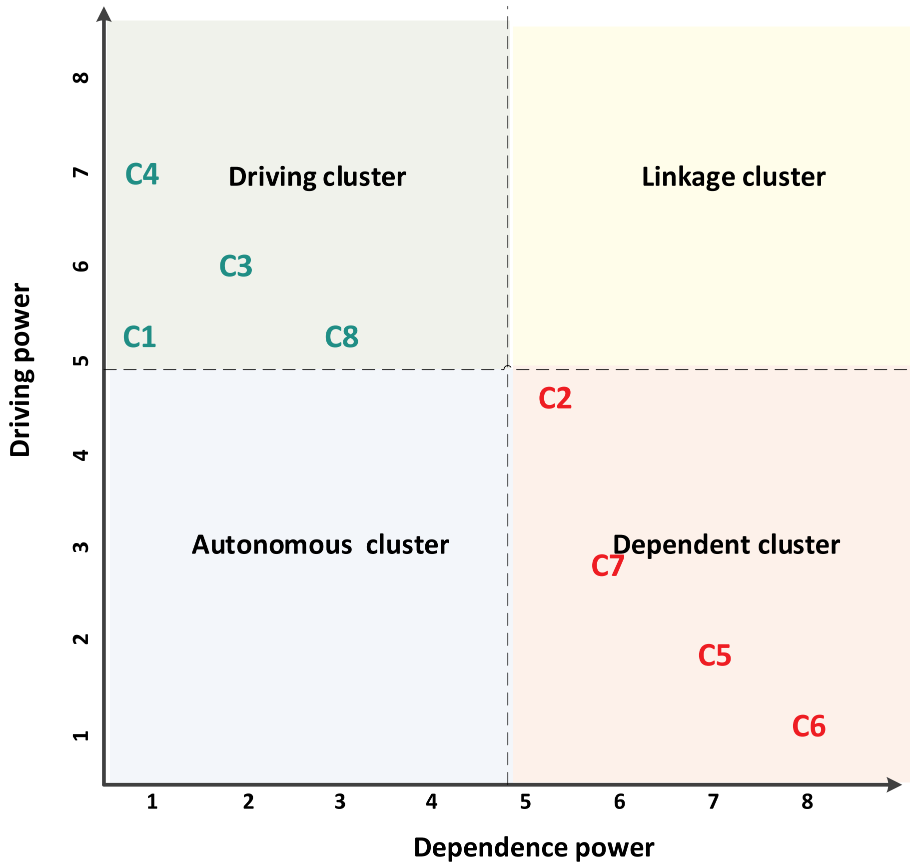

Fig. 4. Driving and dependence power diagram of main challenges.

are driven by other challenges below it. The expert panel believe that the root challenge is managerial challenge which leads to other challenges in the HSCM. Other challenges between managerial challenges and affected people challenge are also very important but policy makers should consider the interrelationships between them. That is, if policy makers would like to make positive changes, they need to invest their time and resources more on the lower part of the model.

According to Fig. 3, the level *I* challenges (unfair assignment of deliveries to affected people and unethical issues), located at the top of the model, are driven by challenges levels *II, III, IV, and V*, so are considered to be dependent challenges. The mid-level challenges (level *II*, *III*, and *IV*) consisting of unaccountability over organizational performance, weak monitoring on recovery operations, lack of cooperation and coordination, and lack of enough funding to finance disaster management, referred to as intermediary factors, are simultaneously driving level *I* challenges and being driven by level *V*. Finally, the challenges located at the base of the diagram (level *V*) are the independent or *root* factors that drive those within levels from *I* to *IV*. We are particularly interested in interpreting the *root* challenges, as their presence causes other challenges. Targeting the *root* causes would have a major impact on increasing the effectiveness of the relief chain and overcoming the challenges in a fundamental manner. Importantly, while the main challenges are related to several phases of HSCM, the root challenges are considered relevant to all four phases (see Table 1). There is a delicate point in the positioning of the eight challenges in Fig. 3. For instance, the most dependent challenges (unfair assignment of deliveries to affected people and unethical issues) are related to post-disaster operations, while the root challenges (unfamiliarity of top managers with management knowledge and inappropriate division of labor) are in relation with both pre- and post-disaster. It means, if challenges are not handled well in pre-disaster phases, there would be more challenges after the occurrence of disasters. Therefore, investing to overcome pre-disaster challenges is more economical than post-disaster ones. This preposition necessitates a particular focus on humanitarian logistics preparedness which is broadly reviewed and discussed by Marianne, Ala, and Luk Van [113]. However, the focus of governments and regional entities has been on disaster *response* for many years, with little attention being paid to disaster reduction strategies that have the potential to save many lives by the simplest of measures [49].

Moreover, our findings emphasize the need for perceiving the different phases of disaster relief as a cycle with having interrelated challenges. In other words, some of the main causes of heavy damage are related to the recovery phase, which could have been overcome in the mitigation phase. One respondent explained that rigid construction regulations should have been enacted and enforced prior to the disaster to mitigate damage. Thus, a mismanaged challenge in the mitigation phase (lack of construction regulations) led to a subsequent challenge in the recovery phase (poor standards to reconstruction). Below, we discuss each of the root challenges in more detail based on the respondents' explanations.

Inappropriate division of labor; based on Table 3, this challenge is associated with all HSCM phases and classified under the *inter-organizational* category. Respondents complained that there are several organizations responsible for a common mission. For instance, for fund raising, more than one organization is involved and even sometimes several organizations are distributing aids between affected people. Further, although there are several national plans and documents, each organization's responsibilities and activities' scope is not very clear yet. This leads to overloads, reworks, parallel responsibilities, and eventually the situation of "tragedy of commons" [114] under which, each organization would like to dodge the assigned common tasks and responsibilities.

Unfamiliarity of top managers with management knowledge; this was recommended by the experts interviewed in this study. This challenge is

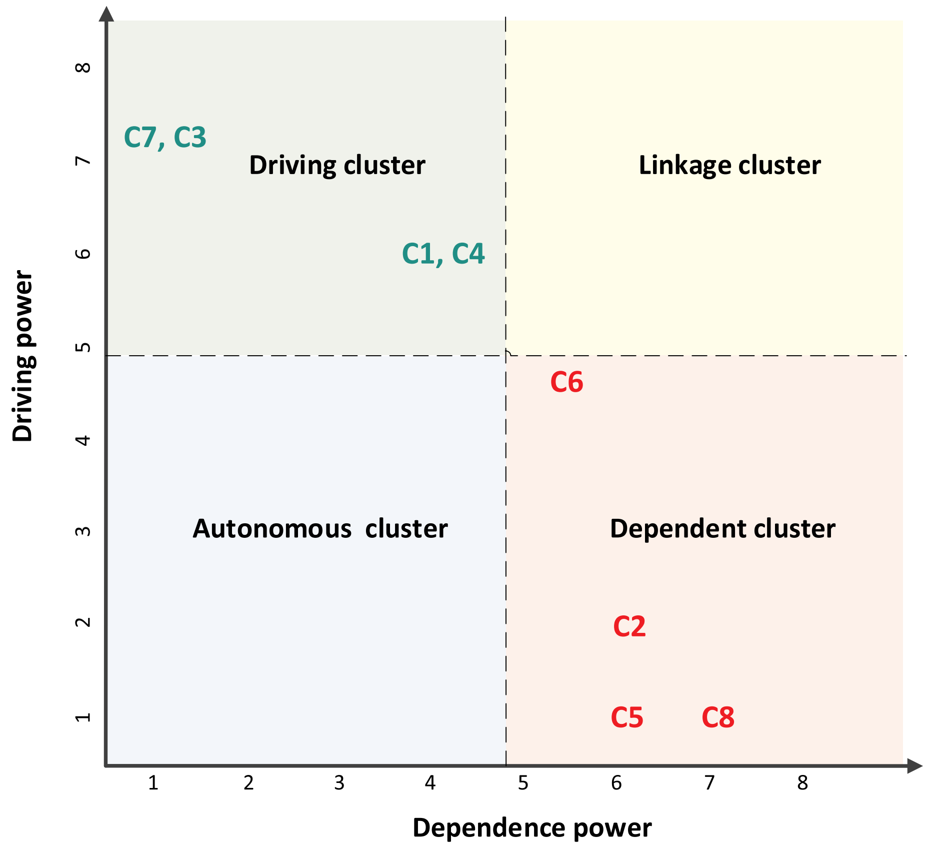

Fig. 5. Driving and dependence power diagram of sub-challenges.

associated with the *managerial* category and impacts HSC performance in all phases of disaster management. It is the driver of two other challenges, namely 'lack of enough funding to finance disaster management', and 'lack of cooperation and coordination among involved actors'. Regarding this challenge, one respondent mentioned that:

> "Employing managers who have relevant experience in the field, especially in the same organization, could improve the manager's fit with their positions. But, scantly new senior managers, in particular CEOs, are ex-lower level managers. Additionally, decentralization and delegation of authority could considerably reduce dependency on the performance of an individual director". Unfortunately, On the other hand, it's not a very long time that some universities developed disaster management programs at masters and PhD level".

Although the 8 challenges are identified as main challenges of humanitarian operations, these results should be interpreted with caution. For instance, referring to Table 3, it is clear that 'lack of cooperation and coordination' has become the most important challenge with a score of 6.54, whereas referring to Fig. 2 it is not positioned as a root challenge. This is due to the fact that based on the proposed framework you need to focus on the cause and effect relationships among the challenges. For instance, lack of cooperation and coordination was also discussed by several studies such as [19], but, to our knowledge, none of them discussed the root cause of it. The authors believe that integrating FDM and FISM provides an enriched and informative picture of HSCM challenges.

But the FISM by itself led to a conceptual model, depicting the cause and effect relationships among the challenges and the hierarchical model of ISM. The PLS was employed to validate the framework (Table 4) and these relationships. The results of the factor analysis show that only one sub-challenge (unpredictability of demand) had a very low relationship with its respective construct (the Environmental challenge) and was removed. Based on the results from structural model and path analysis, only three relationships were rejected statistically; Path from managerial challenges to aid workers challenges, from communication challenges to affected people challenges, and from resources challenges to affected people challenges with the t-values of 0.549, 0.778, and 0.51, respectively. Other relationships identified by the FISM were valid. This indicates that the FISM is very useful in establishing structural relationship between the HSCM challenges.

8. Conclusions

This study was an attempt to identify, develop, and analyze the main challenges of HSCM in Iran with respect to different phases of disaster relief. Accordingly, a total of 51 challenges were identified from the literature review and interviews with 26 experts at the IRCS. The FDM was used to reach a consensus on the main challenges of HSCM, and eight sub-challenges were eventually selected for further analysis by the FISM. Next, the FISM is employed at two levels (main challenges and sub-challenges) to draw a hierarchical structural of the model. This study provided several contributions to both the theory and practice of HSCM challenges.

First, we developed a comprehensive list of 51 HSCM challenges and categorized them into seven categories: Managerial, organizational, inter-organizational, resources, aid workers, affected people, communication, and environmental with paying attention to disaster management phases. The proposed list can be used by scholars as a starting point for further research on the topic and they can identify and propose more barriers and challenges by the proposed methodology of this research. Further, managers can predict their most likely challenging areas by the suggested categories.

Second, this is the first study to develop a holistic picture of the main HSCM challenges considering the cause-and-effect relationships among them. The hierarchical model developed in this research is novel and encompasses eight main challenges located at six levels and eight sub-

Table 9
Factor loadings of sub-challenges.

	Air workers (AW)	Environmental (E)	Managerial (M)	Affected people (AP)	Communication (C)	Inter-organizational (IO)	Organizational (O)	Resources (R)
AP2				0.86				
AP3				0.841				
AP4				0.561				
AW1	0.873							
AW2	0.906							
AW3	0.822							
AW4	0.82							
C1					0.787			
C2					0.738			
C3					0.877			
C4					0.76			
E2		0.884						
E3		0.935						
E5		0.93						
IO1						0.577		
IO10						0.534		
IO11						0.736		
IO12						0.533		
IO13						0.704		
IO2						0.693		
IO3						0.578		
IO4						0.671		
IO5						0.743		
IO6						0.596		
IO7						0.793		
IO8						0.646		
IO9						0.604		
M1			0.555					
M2			0.597					
M3			0.705					
M4			0.62					
M5			0.816					
O1							0.536	
O10							0.567	
O11							0.773	
O2							0.719	
O3							0.761	
O4							0.709	
O5							0.688	
O6							0.679	
O7							0.699	
O8							0.699	
R1								0.842
R2								0.871
R3								0.939
R4								0.691
R5								0.902
R6								0.85
R7								0.793
AP1				0.854				

Table 10
Reliability and convergent validity tests.

	Cronbach's Alpha	CR	AVE
Aid workers	0.878	0.916	0.733
Environmental	0.918	0.94	0.84
Managerial	0.715	0.795	0.552
affected people	0.787	0.865	0.622
communication	0.802	0.87	0.628
inter-organizational	0.887	0.904	0.572
organizational	0.873	0.898	0.511
resources	0.931	0.945	0.713

challenges at five levels which are linked together by arrows. Each arrow explains a relationship between each pair of challenges.

Third, we took the advice from the previous studies like Ghasemian Sahebi et al. [24] and tested our model statistically. To our knowledge, this study was the first effort to statistically validate the relationships between the HSCM challenges in the literature. The hierarchical model of main challenges, makes cause and effect relationships more easily interpretable. The model represents an intertwined network of challenges where the *root* factors are located at the bottom. Findings led us to argue that humanitarian decision-makers should prioritize their investments on the *root* challenges. Practitioners as well, can utilize the hierarchical model to better understand the impact of their policies and solutions against challenges.

Fourth, we proposed a novel hybrid approach to provide a sound understanding of the hierarchical relationships between the HSCM challenges. The hybrid methodology in this research can be replicated in similar studies which require a deep understanding of the interrelated factors.

Considered to be one of the most disaster-prone countries in the world, Iran is susceptible to various types of natural disasters such as storms, floods, droughts, and earthquakes [49]. This study provides new knowledge on the challenges of HSCM in Iran and sets the stage for future research to explore the relevant solutions for each challenge. Thus, the proposed framework of HSCM challenges in other contexts should be used with caution. It is expected that HSCM challenges differ

Table 11
Path analysis and hypothesis test.

Hypothesis No.	Hypothesis	Path Coefficients	Standard Deviation	t-value	Decision
H1	Aid workers > Affected People	0.392	0.197	1.992	Supported
H2	Aid workers > Communication	0.617	0.314	1.965	Supported
H3	Environmental > Aid workers	0.671	0.171	3.924	Supported
H4	Managerial > Aid workers	0.105	0.192	0.549	Rejected
H5	Managerial > Organizational	0.716	0.26	2.754	Supported
H6	Managerial > Resources	0.782	0.077	10.153	Supported
H7	Communication > Affected People	0.167	0.215	0.778	Rejected
H8	Communication > Inter-Organizational	0.243	0.123	1.972	Supported
H9	Inter-Organizational > Affected People	0.410	0.207	1.983	Supported
H10	Organizational > Aid Workers	0.201	0.1	2.013	Supported
H11	Organizational > Affected People	0.570	0.289	1.974	Supported
H12	Organizational > Inter-Organizational	0.652	0.248	2.63	Supported
H13	Resources > Affected People	0.126	0.247	0.51	Rejected
H14	Resources > Organizational	0.200	0.102	1.961	Supported

according to different contextual variables, disaster types, and maturity level of disaster management processes [36].

Despite its contributions and implications, this study has some limitations. First, the FDM methodology requires a significant amount of time from both the researcher and the expert panel. In addition, according to Worrell et al. [94]; qualitative methods such as the FDM and the FISM utilize a ‘non-representative’ sample of experts to explore complex, and multi-disciplinary problems. Therefore, generalizing the opinions of a non-representative group to a larger population can be problematic. In the FDM and FISM models, the inputs and judgments provided by the experts could be biased or unreliable affecting the accuracy and correctness of the hierarchical model. Therefore, applying the results of this study in other contexts, organizations, and countries needs further assessment. In addition, this study is carried out in a developing country, and hence, the results cannot be extrapolated to other countries, in particular developed countries, without caution. Future regional and/or cross-country studies could overcome this limitation.

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