Requirements for Relief Distribution Decision-Making in Humanitarian Logistics

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Abstract. Making efficient and effective decisions in the chaotic environment of humanitarian relief distribution (HRD) is challenging. Decision-makers need to concentrate on numerous decision factors categorized into decision objectives, variables, and constraints. Recent HRD literature focuses on optimizing procedures while neglecting the quantification of essential requirements (decision factors) for information systems to provide decision-making support. In this article, we address this gap by accumulating affecting decision factors from both literature and practice. We investigated the practical implications of these factors in HRD decision-making by measuring the preferences of a Delphi panel consisting of 23 humanitarian experts. The results from our study emphasize the importance of the decision factors in the proposed process model for HRD in a large-scale sudden onset. Our work provides researchers not only with a comprehensive set of practically feasible decision factors in HRD but also with an understanding of their influences and correlations.

Keywords: Natural disasters · Decision support system · Decision factors · Relief distribution · Humanitarian logistics · Delphi technique · Expert preferences

1 Introduction

Although saving lives is the main aim of humanitarian relief operations, it is important to concentrate on minimizing social tension, which increases due to imbalance (inefficiency) in relief distribution (RD). For example, if two distribution centers distribute different relief items, it may fuel tension among recipients depending on which center serves them. Hence, responders need to prepare to standardize relief packages by coordinating with other responding groups and communicate with the recipients to disseminate an RD plan and during the duration of response operations. However, to meet beneficiaries' necessities, responders must know *what* the demanded items are, and *where* and *when* they are needed. For rapid, effective, and efficient response, they also require knowing the accessibility (to transport relief items), warehousing (to store

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them), and distributing arrangements (to reduce social tension) [1]. Moreover, for successful relief operations, understanding and assessing the overall disaster situation (e.g., environment, vulnerabilities, coping mechanisms) is necessary. Thus, responders must acquire geographical, topographical, and demographical knowledge before scheduling RD operations [7].

Identifying such influential decision factors in emergency management – especially in RD – is a complex task [47]. The humanitarian logistics (HumLog) literature proposes plenty of mathematical models and objective functions development by focusing on specific disasters as cases. Researchers utilized diverse variables and constraints in their models and functions for achieving targeted objectives. These factors need to be properly managed and utilized for rapid and effective decision making as they influence the success of the operation [46]. Failure to understand their importance for the information system will make the decision-making process more complex and time-consuming, causing delayed and inadequate responses – or potentially an overall unsuccessful relief operation [29].

By following the work of MacCarthy and Atthirawong [15], Okoli and Pawlowski [26], and Richardson, de Leeuw and Dullaert [34], we rigorously and systematically reviewed and analyzed humanitarian literature to develop a summarized list of decision factors for relief distribution. While sharing some common decision factors (objectives, variables, constraints), the review denoted that five other problem areas (DPA) influence RD decision making: facility location (FL), inventory management (IM), relief supply chain (RSC), transportation (Transp), and scheduling (Sched). For achieving better performance in the complex decision-making operation, decision-makers (DM) in RD need to concentrate on *shared* decision factors as well and assist DMs in other DPAs to achieve their objectives.

However, there has been no structured attempt in RD to identify comprehensive factors and their correlations systematically as well as to prioritize them. This study addresses this gap by empirically testing decision support requirements with the help of the Delphi technique. A worldwide Delphi panel was formed with experts from academia, governments, and national and international NGOs. Their evaluations facilitated consensus and prioritization for each factor and assisted us in answering the following research question: *What decision factors do experts prefer for effective humanitarian relief distribution decision-making?*

To answer this research question, we need to identify experts' preferences in the literature- and field-based decision factors. This investigation will assist us in finding the essential decision factors and understanding their correlations while decision-making for relief distribution. The remainder of this article is organized as follows. We provide the research background in Sect. 2. Section 3 describes our research design. Section 4 presents the results from the Delphi study, and Sect. 5 synthesizes and discusses the findings. We subsequently notify the limitations to this research and suggest implications for future research. Section 6 concludes the article.

2 Research Background

To respond to disasters in a chaotic environment, practitioners conduct complex and challenging tasks. While making decisions on RD, they face uncertainty when identifying appropriate decision factors. Not much research concentrates on recognizing factors that influence decision making in relief distribution. Peres et al. [27] classify operational research (e.g., RD) in HumLog into three DPAs (FL, IM, and network flow and Sched) without presenting influential decision factors. Gralla et al. [12] and Gutjahr and Nolz [14] respectively categorized and refined humanitarian aid operations into *efficiency* (refined into *cost efficiency*), *effectiveness* (refined into *response time*, *travel distance*, *coverage*, *reliability*, and *security*), and *equity* criteria. This classification, categorization, and refinement led towards identifying affecting decision factors and developing a comprehensive set of them. Although Roy et al. [37] listed some factors by dividing the RD process into four sub-processes (FL, IM, Transp, and RD decision), it was not investigated in detail to guide researchers on selecting decision variables and constraints for achieving targeted decision objectives. Safeer et al. [38] and Özdamar and Ertem [47] mapped constraints for specific objectives mainly for transportation and relief distribution but lacked a comprehensive set of decision factors, their priorities, and correlations. We know no research investigating the influences of other DPAs on the decision factors of RD.

However, to improve the disaster management process, adequate decision-making is the key, where prioritized and correlated decision factors play vital roles [4, 22, 43]. According to Li et al. [22], influential factors and their relationships need to be accumulated through proper investigation and experts' judgment. Instead of studying the entire system, current research mostly concentrates on optimizing certain procedures that are extensively case-specific and are rarely used (or unusable) in other cases. To get a holistic image, we accumulated the existing decision support models for humanitarian operations that were implemented in practice in the contexts of sudden natural disasters, thereby collecting practical decision factors. The decision factors accumulated from academic literature are evaluated and utilized in this article to develop a practice-oriented RD process model (Table 1).

3 Research Methodology

3.1 Method Selection

Several techniques were advocated in the humanitarian literature for decision making in different problem areas. We used the Delphi technique to evaluate these factors and to identify new ones. It is suitable for this kind of exploratory research where researchers need to communicate with distantly located practitioners and field experts for dealing with complex and indispensable issues [24, 34]. Although the Delphi technique was successfully utilized by MacCarthy and Atthirawong [15] for investigating and understanding decision factors, it was not widely exploited in humanitarian research. Cottam et al. [8] used the Delphi technique to assess the potential benefit of outsourcing the trucking activities for relief distribution in developing countries. Richardson et al. [34] investigated affecting factors for global inventory prepositioning locations.

Table 1. Literature-based decision factors for relief distribution decision-making

Categories	Decision factors	Literature
10 decision objectives	maximize coverage (cov), maximize transport quantity (tq), minimize travel time (tt), minimize distribution time (dt), minimize travel distance (td), minimize total cost (tc), minimize resource cost (rc), minimize penalty cost (pc), minimize number of distribution centers (ndc), minimize practical length of emergency route (pler)	[5, 6, 12, 23, 32, 33, 35, 42]
13 decision variables	travel distance (td), inventory flow and capacity (ifc), penalty cost (pc), transport cost (trc), operational cost (oc), set-up cost (stc), supply unit (su), beneficiaries access cost (bac), transport quantity (tq), demand time (det), travel time (tt), distribution time (dt), resource need (rn)	
12 decision constraints	storehouse capacity (shc), road capacity (roc), inventory holding cost (ihc), number of storehouses (nsh), budget availability (ba), demand satisfaction (ds), replenishment cost (repc), load flow (lf), transport cost (trc), travel distance (td), operational cost (oc), resource availability (ra)	

The Delphi technique provides an unbiased rating of the decision factors, which further go through ranking and consensus phases for identifying the importance and acceptance of each factor for effective decision-making in disaster-like uncertain situations [17]. Figure 1 illustrates the procedure for our Delphi study, including panel formation and research design.

We invited 76 out of 96 identified experts to participate in the survey. The questionnaire for the first Delphi round was sent to them to confirm their participation. 38 experts replied positively, and 23 finally participated in the survey (i.e., formed the Delphi panel). 17 of the 23 participants completed and returned the questionnaire, the others preferring audio-recorded interviews. We sent the questionnaire for the second round to the 17 who answered the questionnaire experts, of whom 13 responded. The panelists were anonymized according to the guidance of the Norwegian Center for Research Data (www.nsd.no) and the participants themselves. Hence, while conceptualizing panelists' thoughts in Sect. 5, we refer to them with their assigned participant identification numbers (PID in the form of P#).

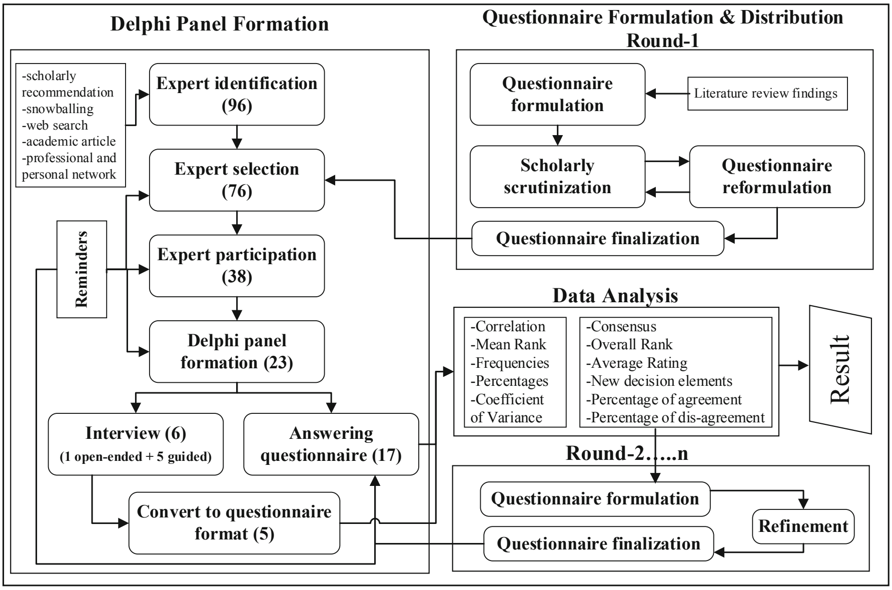

Fig. 1. The process model utilized in this Delphi Study (inspired by [21, 25])

3.2 Delphi Panel Formation

Due to their recency and severity, we targeted the Indonesia earthquakes of 2018 and the Nepal earthquake of 2015. While searching for involved experts having knowledge and interest in RD processes, we established contact with active practitioners and with their networks to gain updated knowledge on their usage of information systems (IS) for relief distribution. Besides, we utilized our contacts and the snowballing technique to bring more experts on-board. As a tentative list of potential participants was ready, we sent a study plan including information on the aim of the Delphi and its rounds, the extent and timing of the expected involvement, expected outcomes, and the potential social benefit to the ones who replied affirmatively. Finally, 23 experts from around the world participated in this Delphi study. The participating experts are listed in Table 2, along with their PID, medium of participation, affiliated organizations, countries, and contributed disasters. With an adequate panel size, according to Grim and Wright [13] and Okoli and Pawlowski [26], we proceeded to the next step. The first-round survey questionnaire was electronically distributed, along with a consent form and a non-disclosure agreement.

3.3 Research Design

Data Collection Method. Instead of starting the process with an open-ended questionnaire or brainstorming sessions, as in traditional Delphi, to identify decision factors in RD [34], we approached participants with existing academic knowledge on such factors. These factors were accumulated, summarized, and clustered into three categories (decision objective, variable, and constraints). We then added them to the questionnaire for experts' evaluation. The factors were explained in the questionnaire that facilitated

Table 2. The Delphi panel

Acronyms: PID-anonymized participant ID, **MPI**-medium of provided informantion, **Q**-questionnaire, **I'**-guided interview, **I''**-open-ended interview				
SL	**PID**	**MPI**	**Affiliated Organization(s) and Country**	**Summary of contributed disasters**
1	P2	Q	World Food Program, Nepal	Earthquake in Eastern Nepal 1988, Haiti 2010, Gorkha 2015 and several other disasters
2	P3	Q	Nepali Army Crisis Management Centre	Earthquake in Gorkha 2015 and several other disasters
3	P6	Q	Papua University, Indonesia	Disaster Risk Reduction in West Papua and several other disasters
4	P8	Q	Universitas Pembangunan Nasional Veteran Yogyakarta, Indonesia.	Merapi and Kelud volcanic disasters
5	P12	Q	Yayasan Dompet Dhuafa Republika, Indonesia	Earthquake in Lombok 2018, Central Sulawesi 2018 and several other disasters
6	P19	Q	World Food Program, Thailand	Earthquake in Haiti 2010, Indonesia 2018 and several other disasters
7	P20	Q	AHA Centre, Indonesia	Earthquake and Tsunami in Central Sulawesi 2018
8	P22	Q	AHA Centre, Indonesia	Indian Ocean Tsunami (2005 – 2008), Earthquake in Padang 2009, Central Sulawesi 2018
9	P24	I'	Kathmando Living Labs, Nepal	Earthquake in Gorkha 2015
10	P25	Q	NetHope & ICE-SA, Iceland	Earthquake in South Iceland earthquakes 2000 & 2008, Sulawesi 2018 and several other disasters
11	P26	Q	Small Wars Journal	Earthquake in Northridge 1992 and several other disasters
12	P39	Q	NetHope, Havard Humanitarian Initiative Center for Humanitarian Data, Northwestern University, USA	Earthquake in Haiti and Nepal and several other disasters
13	P40	I'	WeRobotics, Switzerland	Nearly every major humanitarian emergency for the past 15 years
14	P41	Q	Standby Task Force, USA	Earthquake in Nepal and several other disasters
15	P42	I'	TU Delft, Tilburg University, and consultant for some NGOs and Civil Protection organizations, The Netherlands	Earthquake in Haiti 2010, Philippines 2013, Nepal 2015, Indonesia 2018 and several other disasters
16	P44	Q	UNOCHA, UN Human Rights, UNDAC	Sudan 2004, Niger 2005, Lebanon 2006, Typhoon Haiyan 2013
17	P52	Q	Perkumpulan Lingkar, Indonesia	Earthquake in Jogja 2006
18	P57	I'	National disaster mitigation agency (BNPB) & Mohammodia disaster management, Indonesia	Earthquake in Jogja 2006, Selat Sunda, Sulawesi and Lombok 2018
19	P58	Q	World Food Program, Nepal	August 2017 Floods
20	P63	I''	Federal University of Rio de Janeiro, Brazil	Several humanitarian field works
21	P68	Q	Caritas Germany, Indonesia	Earthquake, Tsunami and Flash Flood
22	P69	Q	WALHI Yogyakarta, National WALHI, Sulteng Bergerak, Selat Sunda Bergerak, SHEEP Indonesia	Earthquake in Yogyakarta 2006, Selat Sunda, Sulawesi and Lombok 2018 and several other disasters
23	P71	I'	World Food Program, Indonesia	Earthquake in Selat Sunda, Sulawesi and Lombok earthquake 2018 and several other disasters

respondents to rate each decision factor on a six-point Likert Scale (inspired by [40]). Respondents were also given space to express their understanding of each of the factors and propose new factors from the practical field. However, if a participant found it complicated to answer the questionnaire, they had the opportunity to express their opinion through interview sessions (physical or online). As a result, we gained qualitative insights for the entire RD process (inspired by [44]). Additionally, to understand the depth of influences, participants were requested to mark the relationship of each decision factor of RD to the other five problem areas (FL, IM, RSC, Transp, and Sched). Thus, we incorporated relevant and in-depth information for the research quest (inspired by [18]).

Consensus and Stability. To decide on achieving consensus, we adopted the *Average Point of Majority Opinions* (APMO) technique by Kapoor [20]. A decision factor would be considered as achieving consensus if its agreement or disagreement is above the cut-off rate of APMO. Instead of considering consensus achievement as a tool to decide on further Delphi rounds, we verified how a certain percentage of votes fall within a prescribed range, i.e., how the experts react to different decision factors. We identified no clear instruction on deciding on the number of Delphi rounds for studies. Hence, by following Dajani and Sincoff [9] and Strasser [41], we calculated the *coefficient of variance* (CV) to decide Delphi rounds and check their consistencies. Finally, we utilize SPSS software to calculated *Kendall's concordance coefficient* (W) to measure the degree of agreement among panel members ($W = 0$ means perfect disagreement and $W = 1$ means perfect agreement). $W = 0.7$ is considered as an indication to achieve a higher level of general agreement in Delphi studies [39]. We demonstrate consensus and stability in Sect. 4 and discuss them in Sect. 5.

Delphi Rounds. After finalizing the list of experts, we started *round-1* by commencing the Delphi process by sending the questionnaire to each panel member in December 2018. Although an online survey is a typical mode for the Delphi technique [34, 40], emailing the questionnaire – e-Delphi – is also practical [2, 3, 25]. In addition to survey questions, the questionnaire captured the professional background for each respondent. We collected responses until February 2019. Data accumulated from the first round of the Delphi survey were extracted for descriptive analysis for finding frequencies and percentages. We utilized MS Excel and IBM SPSS to find correlations among factors and different statistics, such as the mean rank and Kendall's W. Furthermore, we utilized APMO to determine whether each factor achieved consensus. In *round-2*, the result generated from the collective feedback in the first Delphi round was shared with all the panel members in March 2019. We redesigned the questionnaire to inform about the average rating, percentage of agreement and disagreement, overall ranking, and achieving consensus for each decision factor. The respondents were provided with their previous rating for each of the decision factors and allowed to update it (inspired by [36]). The newly identified practical decision factors from round-1 were added to the questionnaire to be evaluated.

4 Results

4.1 Descriptive Information on the Participants

Most panel members have extensive working experience, some of whom worked for more than 25 years in this sector. They participated or are participating in the response operations for large-scale natural and human-made disasters worldwide, for example, the South Iceland earthquakes 2000 and 2008, the Haiti earthquake 2010, the Gorkha (Nepal) earthquake 2015, the Indonesia earthquake 2018, different devastating hurricanes and floods, the 2014–2016 Ebola outbreak in West Africa, and the Syria crisis. Their heterogeneous experiences on responding to various crises and disasters assist us in evaluating the influential decision factors.

4.2 Measurement of Stability and Stopping Criterion

To achieve stability and to stop further rounding, English and Kernan [11] quantified $0 < CV \leq 0.5$. In the first Delphi round, we had four factors in three decision-making categories (one in decision objectives and constraints, and two in decision variables) that were in the border or out of the suggested range of achieving general agreement ($CV \geq 0.5$). Besides, Kendall's W value for each category was very low (for objectives $W = 0.181$, for variables $W = 0.133$, and for constraints $W = 0.26$). Therefore, we conducted the second round, where the four decision factors achieved a good degree of consensus with $CV \leq 0.39$. Then, we measured the CV difference and defined the stopping rule as a CV difference of $\leq$ 0.3 (inspired by [41]). However, there were significant improvements (although still not high) in the degree of agreement in all categories in the second Delphi round (for objectives $W = 0.194$, for variables $W = 0.213$, and for constraints $W = 0.470$). Finally, receiving an absolute CV difference of $\leq$0.26 for each factor in every decision-making category and improved value for Kendall's W constituted stability, we decided to terminate conducting any additional Delphi round (inspired by [9, 10]).

4.3 Results of the Delphi Rounds

Literature-Based Decision Factors. Table 3 demonstrates the combined statistical results for two Delphi rounds. It illustrates the consensus and ranking for each decision factor incorporated into three categories for relief distribution (decision objectives, variables, and constraints). We easily compare the responses in both rounds and visualize the changes made by the respondents in the second round. For convincingly presenting the result, we clustered decision factors up to the third level of importance: achieving an average rating (AR) of $\geq$5.00 was considered as *highly important* decision-making factor and placed in cluster-1, whereas factors satisfying $5.00 > AR \geq 4.00$ were considered in cluster-2 as *mediocre* and the rest with $AR < 4.00$ were in cluster-3 as *least affecting* factors.

Decision Objective. In Delphi round-1, 76.8% of the experts rated all listed decision objectives as important topics in the relief distribution decision-making, whereas 19.6% found them unimportant, and 3.6% abstained from commenting. Among those decision objectives, *travel time minimization* and *coverage maximization* were placed in cluster-1 as the most important objectives that responders try to achieve without considering *minimizing* different *costs* (*total, resource, penalty*) and the *number of distribution centers*, hence placed in cluster-3. The mediocre category (cluster-2) encompassed factors that were mostly related to transportation and distribution. The result suggested *transporting a maximum quantity* of relief items by choosing a *practically short emergency route* that would *minimize travel distance* and *distribution time*. In Delphi round-2, 78.5% of experts voted as important properties of decision making, and 21.5% voted not to consider. However, a significant change was observed in this round, where coverage maximization was downgraded, and all the topics from cluster-3 were upgraded to cluster-2. The only topic remained in cluster-3 was resource cost minimization.

Inspecting the consensus, we can identify that transport quantity from cluster-2 and all the topics in cluster-3 did not receive general agreement from the participants in the first Delphi round. However, they continued not to receive consensus in the second Delphi round as well, but for the topic of transport quantity. Its AR was upgraded to 4.8 and secured its consensus with 92.3% vote in round-2. Except for the down-graded topic of travel distance, all topics in cluster-1 and -2 gained their votes to be importantly

Table 3. Combined statistical results for Delphi rounds 1 and 2 (inspired by [8, 41])

Acronyms: UAC: Unable to Comment; TO: Total Opinion; TP: Total Point; MP: Mean Point; SD: Standard Deviation; MR: Mean Rank; FR: Final Rank; CV: Coefficient of Variance; A.Total: Answering Total; C.Total: Consensus Total; **Please consult Table 1 for acronyms

SL	Attributes**	Round 1														Round 2												Stability(CV1-CV2)	Test Statistics
		Consensus (APMO)								Ranking						Consensus (APMO)						Ranking							
		UAC		Disagreed (1-3)		Agreed (4-6)		TO1	Consensus1	TP1	MP1	SD1	MR1	FR1	CV1	Disagreed (1-3)		Agreed (4-6)		TO2	Consensus2	TP2	MP2	SD2	MR2	FR2	CV2		
		#	%	#	%	#	%									#	%	#	%										
Decision Objectives																													
1	cov	0	0	3	13.6	19	86.4	22	Y	111	5.05	1.1	6.7	3	0.22	2	15.4	11	84.6	13	Y	62	4.8	1.1	5.73	5	0.23	-0.01	Round 1: Kendall's W 0.181 Round 2: Kendall's W 0.194
2	tq	1	5	4	18.2	17	77.3	21	N	92	4.18	1.6	5.36	5	0.39	1	7.69	12	92.3	13	Y	62	4.8	1	5.96	4	0.21	0.176	
3	tt	0	0	1	4.55	21	95.5	22	Y	112	5.09	0.9	6.89	1	0.18	1	7.69	12	92.3	13	Y	66	5.1	1	6.88	2	0.19	-0.01	
4	dt	1	5	3	13.6	18	81.8	21	Y	109	4.95	1.6	6.89	2	0.31	2	15.4	11	84.6	13	Y	66	5.1	1.2	7.12	1	0.23	0.08	
5	td	0	0	6	27.3	16	72.7	22	N	90	4.09	1.3	4.68	7	0.31	5	38.5	8	61.5	13	N	52	4	1.5	4.19	9	0.37	-0.06	
6	tc	1	5	8	36.4	13	59.1	21	N	83	3.77	2	4.86	6	0.54	5	38.5	8	61.5	13	N	53	4.1	1.6	4.85	7	0.39	0.142	
7	rc	0	0	8	36.4	14	63.6	22	N	85	3.86	1.4	4.52	8	0.36	4	30.8	9	69.2	13	N	51	3.9	0.8	3.88	#	0.19	0.166	
8	pc	2	9	4	18.2	16	72.7	20	N	83	3.77	1.6	4.18	10	0.42	3	23.1	10	76.9	13	N	58	4.5	1.1	5.15	6	0.24	0.189	
9	ndc	2	9	5	22.7	15	68.2	20	N	83	3.77	1.7	4.34	9	0.44	3	23.1	10	76.9	13	N	56	4.3	1	4.73	8	0.24	0.201	
10	pler	1	5	1	4.55	20	90.9	21	Y	105	4.77	1.4	6.57	4	0.29	2	15.4	11	84.6	13	Y	62	4.8	1.2	6.5	3	0.24	0.044	
A.Total		8	4	43	19.6	169	76.8									28	21.5	102	78.5										
C.Total				0		169		212	80							0		102		130	78.5								
Decision Variables																													
1	td	0	0	7	31.8	15	68.2	22	N	93	4.23	1.4	6.59	10	0.33	3	23.1	10	76.9	13	N	59	4.5	1.3	7.12	7	0.29	0.033	Round 1: Kendall's W 0.133 Round 2: Kendall's W 0.213
2	ifc	0	0	4	18.2	18	81.8	22	Y	98	4.45	1.1	6.86	7	0.24	2	15.4	11	84.6	13	Y	62	4.8	0.9	6.96	8	0.19	0.043	
3	pc	2	9	7	31.8	13	59.1	20	N	78	3.55	1.8	5.09	13	0.51	5	38.5	8	61.5	13	N	50	3.8	1.2	4.38	#	0.32	0.19	
4	trc	1	5	10	45.5	11	50	21	N	77	3.5	1.9	5.32	12	0.54	7	53.8	6	46.2	13	N	50	3.8	1.6	4.73	#	0.41	0.133	
5	oc	0	0	8	36.4	14	63.6	22	N	86	3.91	1.5	5.68	9	0.38	4	30.8	9	69.2	13	N	53	4.1	1.2	4.96	#	0.29	0.087	
6	stc	1	5	5	22.7	16	72.7	21	N	86	3.91	1.7	5.93	11	0.43	3	23.1	10	76.9	13	N	55	4.2	1	5.58	#	0.24	0.192	
7	su	1	5	4	18.2	17	77.3	21	Y	94	4.27	1.4	6.75	8	0.32	0	0	13	100	13	Y	63	4.8	0.7	7.92	5	0.14	0.174	
8	bac	1	5	5	22.7	16	72.7	21	N	94	4.27	1.6	6.91	6	0.38	2	15.4	11	84.6	13	Y	60	4.6	1.1	6.96	9	0.24	0.141	
9	tq	0	0	2	9.09	20	90.9	22	Y	104	4.73	0.9	7.86	5	0.19	0	0	13	100	13	Y	66	5.1	0.6	8.69	2	0.13	0.061	
10	det	1	5	4	18.2	17	77.3	21	Y	103	4.68	1.6	8.43	3	0.35	2	15.4	11	84.6	13	Y	64	4.9	1.3	8.58	3	0.27	0.083	
11	tt	1	5	2	9.09	19	86.4	21	Y	106	4.82	1.4	8.43	2	0.29	2	15.4	11	84.6	13	Y	64	4.9	1	8.31	4	0.21	0.08	
12	dt	2	9	1	4.55	19	86.4	20	Y	104	4.73	1.8	8.27	4	0.37	1	7.69	12	92.3	13	Y	63	4.8	0.9	7.81	6	0.19	0.185	
13	rn	1	5	2	9.09	19	86.4	21	Y	111	5.05	1.5	8.86	1	0.3	1	7.69	12	92.3	13	Y	67	5.2	1	9	1	0.19	0.111	
A.Total		11	4	61	21.3	214	74.8									32	18.9	137	81.1										
C.Total				10		203		275	77							7		131		169	81.7								
Decision Constraints																													
1	shc	1	5	4	18.2	17	77.3	21	Y	102	4.64	1.8	7.91	2	0.39	1	7.69	12	92.3	13	Y	66	5.1	1	8.12	5	0.19	0.198	Round 1: Kendall's W 0.260 Round 2: Kendall's W 0.470
2	roc	0	0	4	18.2	18	81.8	22	Y	103	4.68	1.2	7.7	4	0.25	3	23.1	10	76.9	13	N	62	4.8	1.2	7.23	7	0.24	0.006	
3	ihc	1	5	10	45.5	11	50	21	N	78	3.55	1.5	4.43	11	0.42	6	46.2	7	53.8	13	N	49	3.8	1.1	3.81	#	0.29	0.134	
4	nsh	1	5	6	27.3	15	68.2	21	N	86	3.91	1.7	5.41	10	0.43	2	15.4	11	84.6	13	Y	55	4.2	0.9	5.04	#	0.22	0.213	
5	ba	2	9	1	4.55	19	86.4	20	Y	99	4.5	1.9	7.52	6	0.42	0	0	13	100	13	Y	67	5.2	0.8	8.62	1	0.16	0.26	
6	ds	2	9	1	4.55	19	86.4	20	Y	105	4.77	1.8	7.86	3	0.38	0	0	13	100	13	Y	65	5	0.9	8.19	4	0.18	0.194	
7	repc	1	5	12	54.5	9	40.9	21	N	68	3.09	1.4	3.18	12	0.47	8	61.5	5	38.5	13	N	42	3.2	0.9	1.96	#	0.29	0.18	
8	lf	1	5	3	13.6	18	81.8	21	Y	102	4.64	1.6	7.16	7	0.36	2	15.4	11	84.6	13	Y	64	4.9	1.3	7.54	6	0.26	0.101	
9	trc	0	0	7	31.8	15	68.2	22	N	87	3.95	1.6	5.55	8	0.42	3	23.1	10	76.9	13	N	56	4.3	1.3	5.58	8	0.29	0.126	
10	td	1	5	2	9.09	19	86.4	21	Y	102	4.64	1.4	7.59	5	0.29	1	7.69	12	92.3	13	Y	66	5.1	0.9	8.38	3	0.17	0.124	
11	oc	1	5	8	36.4	13	59.1	21	N	84	3.82	1.7	5.41	9	0.44	5	38.5	8	61.5	13	N	54	4.2	1.1	5.08	9	0.28	0.165	
12	ra	1	5	3	13.6	18	81.8	21	Y	106	4.82	1.6	8.27	1	0.33	2	15.4	11	84.6	13	Y	67	5.2	1.1	8.46	2	0.21	0.123	
A.Total		12	5	61	23.1	191	72.3									33	21.2	123	78.8										
C.Total				12		171		252	73							8		118		156	80.8								

considered in the relief distribution decision-making process. Finally, the voting for total cost was unstable (as CV > 0.5) in round-1 and achieved its stability in round-2.

Decision Variables. To find important decision-making variables in round-1, 74.8% of panel members positively rated the factors in this category, whereas 21.3% finds them unimportant, and 3.9% did not vote. In round-2, 81.1% voted to list them as important decision factors. However, by analyzing the voting result, we identified that resource need was placed in cluster-1 in both rounds, whereas the transporting quantity of relief items accompanied it in round-2. All costing-related topics (penalty, transportation, operational, and set-up) secured their places in cluster-3 in round-1, except beneficiaries' access cost. It was listed in cluster-2 along with travel distance, inventory flow and capacity, supply unit, transportation quantity, and demand, travel, and distribution time. There was no such significant change in round-2. Operational and set-up cost upgraded to cluster-2, and as already mentioned, transportation quantity joined resource need in cluster-1. Although travel distance was a mediocre affecting decision factor, it did not achieve general agreement along with all factors from cluster-3 in the first round. However, all the non-consensus factors in the first round remained unchanged in the second round, except beneficiaries' access cost. It secured its consensus with 84.6% of the general agreement in the final round. Lastly, the rating for penalty cost and transportation cost were unstable (as $CV > 0.5$) in round-1 that became stable in round-2.

Decision Constraints. The decision factors in this category already achieved stability as $CV < 0.5$ for each of them in Delphi round-1, and this stability became higher in round-2 as $CV \leq 0.29$. However, the analysis found no highly important decision factor for cluster-1 in the first round. Seven out of 12 decision-making constraints were considered as mediocre and placed in cluster-2, while the remaining ones were encompassed in cluster-3. The factors constituted this category gained their maximum percentage of general agreement in round-1, which remained the same in round-2 as *road capacity,* and the *number of storehouses* switched their places in achieving consensus. However, five decision constraints (*storehouse capacity, budget availability, demand satisfaction, travel distance, and resource availability*) from cluster-2 gained higher importance in the second round and moved to cluster-1, which was the maximum content of this cluster. 72.3% of the panel members agreed to consider the listed factors as important decision-making constraints in round-1, whereas 23.1% were not convinced, and 4.6% were unable to comment. In round-2, 78.8% voted for enlisting these factors as decision-making constraints in the intended decision support system (DSS), whereas 21.2% voted not to.

Field-Based Decision Factors. While evaluating the decision factors in round-1, the panelists were requested to recommend essential factors missing so far. Out of 23 panelists, 13 contributed to suggesting additional decision factors based on their experiences. After analyzing and refining, three new decision objectives were identified, whereas 13 new decision variables and ten new decision constraints were enlisted for further evaluation in round-2. The panel members were requested to follow similar evaluating procedures as that of in the first round. This evaluation procedure facilitated panel members with a chance to know and verify the new decision factors proposed by other members. Table 4 demonstrates the newly recommended decision factors, along with the results from the analysis that is subsequently discussed.

After analysis, we identified that two decision objectives, six decision variables, and three decision constraints achieved consensus with over 90% vote and hence, prioritized into the list though their mean rank is lower (please consult Table 4 for detail). Although other decision factors did not achieve consensus, their importance in the decision-making process was significant as they scored over 76% vote. For example, what would be the reason for tending to reduce central control on the *financial flow and other decisions*?

Table 4. Field-based decision factors for relief distribution decision-making

SL	Experts preferring new decision factors	Consensus						Ranking					
		Disagreed (1-3)		Agreed (4-6)		Total openion	Consensus (APMO)	Total Point	Mean Point	Standard Deviation	MeanRank (SPSS)	Final Rank (SPSS)	Kendall's W (SPSS)
		#	%	#	%								
Objectives													
1	Central influence on financial flow and other decision (minimize)	3	23.08	10	76.92	13	N	52	4	1.08	1.31	3	W=0.644
2	Proper Operational Mgt model by maximizing social capital	0	0	13	100	13	Y	66	5.08	0.86	2.15	2	
3	Proper response plan for minimizing social tension	0	0	13	100	13	Y	72	5.54	0.78	2.54	1	
	Consnesus calculation	0		36		39	92.31						
Variables													
1	Assessing local sources of supplies	0	0	13	100	13	Y	68	5.23	0.73	8.35	3	W =0.184
2	Relief package standerdization (heavy, lightweight, etc.)	3	23.08	10	76.92	13	N	57	4.38	1.19	5.54	12	
3	Duration of response operation	2	15.38	11	84.62	13	N	58	4.46	1.33	6.27	9	
4	Understanding and assessing the disaster situation (environment, vulnerabilities, and coping mechanisms)	1	7.692	12	92.31	13	Y	67	5.15	1.21	8.77	2	
5	Need assessment for current and future operations (victims' locations, items' and victims' categorization, prioritization, and quantity, difficulties to make the materials available to them)	1	7.692	12	92.31	13	Y	69	5.31	1.44	9.46	1	
6	Synchronization of need and operation: think of the responding capacity (from warehouse to the field) before deployment	2	15.38	11	84.62	13	N	60	4.62	1.12	6.81	7	
7	Knowledge acquisition on previous incidents and analysis	2	15.38	11	84.62	13	N	59	4.54	1.2	5.62	11	
8	Digital communicating devices	3	23.08	10	76.92	13	N	59	4.54	1.27	6.42	8	
9	Traffic control plan at distribution points	3	23.08	10	76.92	13	N	61	4.69	1.25	7.42	5	
10	Social capital (support from local leaders, experts or community)	2	15.38	11	84.62	13	N	56	4.31	1.6	5.38	13	
11	Targeted community's cultural knowledge or understanding	1	7.692	12	92.31	13	Y	66	5.08	1.19	8.23	4	
12	Relief distribution plan sharing with the beneficiaries	1	7.692	12	92.31	13	Y	59	4.54	1.13	5.69	10	
13	Knowledge on neighboring regions; geographical, topography and demography knowledge about the targeted point of distribution	1	7.692	12	92.31	13	Y	63	4.85	0.9	7.04	6	
	Consnesus calculation	0		147		169	86.98						
Constraints													
1	Characteristics of disasters	2	15.38	11	84.62	13	N	57	4.38	1.26	5.12	7	W = 0.166
2	Characteristics of affected areas	2	15.38	11	84.62	13	N	62	4.77	1.42	6.15	3	
3	Access to the point of distribution	1	7.692	12	92.31	13	Y	64	4.92	1.12	6.69	2	
4	Civil-military relationship	2	15.38	11	84.62	13	N	60	4.62	1.04	5.23	6	
5	In-country political situations	1	7.692	12	92.31	13	Y	62	4.77	1.17	5.5	5	
6	Safety and security to respondents, relief supply chain, and beneficiaries	1	7.692	12	92.31	13	Y	66	5.08	1.19	7.27	1	
7	Social and communication infrastructure	2	15.38	11	84.62	13	N	54	4.15	0.99	3.73	10	
8	Geographical and environmental (weather) conditions of the disaster area	2	15.38	11	84.62	13	N	60	4.62	1.39	5.12	8	
9	Coordinating with other relief distributing groups (big/small)	3	23.08	10	76.92	13	N	58	4.46	1.45	4.58	9	
10	Trained, committed and technology supported volunteers/supporting staffs	2	15.38	11	84.62	13	N	61	4.69	0.95	5.62	4	
	Consnesus calculation	0		112		130	86.15						

Again, from the general observation, it can be understood that most of the panelists suggested having decision-making flexibility in the field, but we do yet not know the actual reasoning. If the rating for this attribute is analyzed, it seems that participants were, somehow, confused to claim that flexibility because 8 out of 10 agreeing participants rated 4 out of 6, whereas 2 out of 3 disagreeing participants rated 3 and in the Likert scale of 6, rating of 3 and 4 are normally meant as *confusing*. Thus, further study is essential. Additionally, based on experts' ranking, these new decision attributes were finally ranked by using the *mean rank* calculated by SPSS software. Furthermore, the degree of agreement among panel members (Kendall's W) was also measured. The Kendall's W for new decision objectives was measured as 0.644; 0.7 is considered as a higher level of general agreement. Hence, it was decided to conclude the Delphi survey though Kendall's W for the other two categories were not that high – for decision variables $W = 0.184$ and for decision constraints $W = 0.166$.

Final Ranking. Over 76% of the panelists in round-1, voted to include all the literature-based decision factors in the relief distribution decision-making; over 81% voted this way in round-2. The field-based decision factors received an overall vote of over 77% to accept them in the decision-making process. Thus, the importance of these comprehensive decision factors in the envisioned DSS for relief distribution was accomplished.

Therefore, combinedly the number of enlisted decision factors became large: 13 decision objectives, 26 decision variables, and 22 decision constraints. This bigger list of decision factors is impractical to suggest to the decision-makers and will be challenging to manage in the crucial responding time. Hence, a comprehensive and prioritized list of decision factors is needed.

We further analyzed the consensus regarding highly ranked decision factors in both lists. To be enlisted as highly influential decision-making attributes, literature-based decision factors must accomplish over 80% vote in both Delphi rounds, whereas decision factors from the practice must ensure over 90% vote in round-2. We, thus, identified and enlisted six decision objectives, eight decision objectives, and eight decision constraints as the most influential decision factors for humanitarian relief distribution. Table 5 presents a comprehensive list of top-ranked decision factors, along with the vote percentage. To present them conveniently, we placed the field-based decision factors just after that of the scientific literature.

Table 5. The most effective decision factors for relief distribution decision-making

Decision Factors		Vote (%)	Sources
Objectives	**1.** Travel time (minimize)	93	Scientific literature
	2. Emergency route length (minimize)	85	
	3. Coverage (maximize)	83	
	4. Distribution time (minimize)	81	
	5. Social tension (minimize)	100	Expert preferences
	6. Social capital (maximize)	100	
Variables	**1.** Transportation quantity	95	Scientific literature
	2. Resource need	88*	
	3. Distribution time	88	
	4. Travel time	83	
	5. Inventory flow and capacity	81	
	6. Assessing the situation and local markets	96	Expert preferences
	7. Knowledge in neighboring regions and culture of the targeted community	92	
	8. Relief distribution planning and sharing	92	
Constraints	**1.** Budget availability	93*	Scientific literature
	2. Demand satisfaction	93	
	3. Travel distance	88	
	4. Resource availability	81*	
	5. Load flow	81	
	6. Safety and security	92	Experts preferences
	7. Access to the point of distribution	92	
	8. In-country political situations	92	
*also recommended by the experts			

5 Synthesis and Discussion

In this section, we synthesize our findings from the Delphi process and discuss them category-wise. Afterward, by exploiting the result, we draw a correlational matrix and propose a relief distribution process model. Finally, we conclude this section by discussing the challenges and portraying our future research directions.

Firstly, distributing a maximum of relief items within a short period is the main objective of the humanitarian operations undertaken in response to disasters [5]. For successful humanitarian operations, DMs always try a fast response and to meet as many demands as possible [16]. In doing so, the operation must be forecasted with adequate data for need assessment. P12 exemplified the context of the Indonesian Earthquake 2018 to point out that the process should prioritize acquiring and assessing demand data before focusing on serving maximum needs. According to the participant, this is sometimes absent in the process operated in the field. To speed up the process, P44 and P52 suggested focusing on fulfilling the basic needs with quality relief items instead of quantity of relief demand. P24 came with a unique idea of publicly forecasting the need information to serve maximum demand by incorporating the concept of *social capital*. After sudden-onset, initial responses come from the people inhabiting in neighboring communities when organizational support is still unavailable (P41, P42, P57). So, if they can be forecasted with frequently updated need information, more demands can be served to save more lives. By monitoring communal services, national or international responders can avoid allocating funds for relief items that may stay unused or become surpluses (P24, P25). This will provide flexibility to responders for meeting important demands that are still missing. However, P40 recommended to *"…prioritize remote regions for relief operations as small and mediocre organizations keep those regions out of their distribution plans to minimize expenditure"* though *operational cost* and *social tension* may increase. According to P20 and P71, the success of any relief operation largely depends on the instructions from the sourcing organizations (e.g., hosting government, United Nations) and their mission objectives and capacity.

Speed is one of the critical success factors of relief distribution [29]. When a responding team is planning to serve maximum demands, it needs to find its way(s) for faster mobilization of maximum relief items (*transport quantity*) to the affected population [16]. According to P26, *minimizing travel time* would ensure timely relief distribution (*distribution time minimization*) by increasing the potential number of trips of shipments. Although it is important to *shorten travel time*, the access constraints need to be considered during emergencies (P58). For example, extreme weather conditions made the relief operation challenging in the East part of Indonesia, where P12 participated. Hence, P24 suggested placing demand notation into a map so that central DMs can select the *shortest practical length of the emergency route*(s) (hence, *shorter travel distance*) and calculate *minimum travel time* to the demand points from the nearest distribution center(s). However, participants identified that *minimizing travel time* is more important than *coverage maximization*. Thus, the later factor was re-evaluated in round-2 and listed cluster-2. It would make the entire operation unsuccessful if maximum coverage is planned without minimizing travel time. Hence, P41 remarked, *"…do well in one area rather than poorly in all areas"*. Furthermore, the cost-related factors are theoretically important (P58), but practically *"…saving lives and providing basic needs and* *medical treatment are of paramount importance as compared to the cost involved"* (P3). However, although some participants were in favor of having reasonable (or more) distribution centers for serving affected people, others were not concentrating on this issue as this topic is directed to the central logistics hub.

Secondly, for achieving the objectives of humanitarian assistance and successfully distributing relief items, DMs are required to control some variables [37]. Among the 13 listed decision variables, panel members considered, in the first place, balancing *resource need* and relief *transportation quantity* to meet demands at the targeted point of distribution (POD). In doing so, multiple panel members suggested to categorize and prioritize peoples' needs before dispatching relief vehicles, whereas P24 and P40 emphasized to share the distribution plan beforehand to gain beneficiaries' satisfaction. For example, the relief packages can be standardized by categorizing the recipients by age, gender, location, households, family member, etc. and if they are informed earlier about the package (food/non-food, heavy/lightweight), they can ensure their arrangements (*beneficiaries' access cost*) to receive relief package(s) and return home safely. This will ensure the reduction of *social tension*, which is one of the most critical and complex issues to tackle in the disaster-arisen chaotic field (P40). Furthermore, to face such challenges, it is also necessary to maintain reduced travel and distribution time that can be done by establishing *supply unit(s)* with *sufficient storing capacities* in shorter *travel distance*, accelerating inventory flow for shortening *demand meeting time.*

However, none of the cost related issues (*penalty, transport, operational, and set-up cost*) gained ultimate consensus and hence, rank low. According to the participants, achieving cost-benefit may be important in business logistics, not in HumLog. P3 expressed that *"…importance should be given to the mechanism to transport the relief materials as quickly as possible and not the cost involved"*. Nonetheless, P40 criticized the hidden cost-benefit issue in humanitarian operations that restrict NGOs to support remote communities. The participant suggested prioritizing those communities while planning for deployment as they are not covered in most of the cases, and if necessary, this can be negotiated with the donors for supporting responding operations in better ways.

Thirdly, to operate an effective and efficient relief distribution, DMs need to satisfy limiting constraints that are not directly controlled by them. For example, *budget* and *resource availability*, *travel distance*, and *storehouse capacity* gained maximum attention. Humanitarian operations largely depend on donors [19], and humanitarian organizations have no line of credit (P40). Although it is expected to have an adequate budget to support the entire relief distribution mechanism (P3), it is always difficult to convince donors to increase the budget, even if it is needed to cover more survivors in remote areas (P19, P41). Additionally, if the required items (resources) are unavailable in the hosting area (e.g., local market), the logistical costs become higher and affect the entire operation (P24). On the other hand, the *number of storehouses* and their *capacities* are centrally controlled and always face space unavailability to the upcoming shipments waiting in the port to be unloaded (P57, P58). Although P71 was mentioning to arrange mobile storages, it would, however, increase *operational cost* and relief *distribution time.* Furthermore, unavailable access points would delay the distribution process by limiting *road capacity* or *traveling longer distances* (P40, P44). This results in an irregular *load flow; inventory holding cost* and *replenishment cost* would increase significantly.

Moreover, geographical location, security, political instability, and weather of the hosting area(s) always bring uncontrollable situations to the operations. Besides, having support from the hosting government and the military, responding teams must be careful while tackling such situations. P19 and P41 suggested to incorporate local informants for continuous situational updates on further sections of a distributing network, and local transport provides as they know the local road-links. Hence, P24 was envisioning a technological system where local communities can post information on certain issues that are further refined by system analysts and graphically presented into a distribution network map. This would help DMs to find alternatives.

Fourthly, after getting a clear understanding of decision factors and their influences on the relief distribution process, it is important to know how each factor in decision objectives is correlated with that of in decision variables and constraints. Table 6 illustrates the positive and negative correlations. For positive correlation, we considered a correlation coefficient of ≥ 0.3; for negative correlation, we notated all of them although some values were insignificant. By doing so, we warn DMs, in case they intend to consider these factors for the process. The presented correlation matrix guides DMs to select appropriate variables and constraints for achieving certain objectives. By consulting the correlational values in the matrix, DMs can rapidly decide on the factors that are necessary for supporting decision-making and can thus produce decision alternatives for efficient and effective relief distribution.

Although most of the cost related topics did not achieve consensus and were ranked low, some of them show high correlational significance. For example, the operational cost has the highest impact when practitioners intend to transport maximum relief items to different PODs. It scored highest in both decision variables (0.78) and decision constraints (0.6) categories. This justifies that DMs working in the down-stream of the humanitarian supply chain are not fully independent while budgeting operational costs. They are controlled (to some extent) by donors and central authorities of respective organizations. They may face similar situations when deciding on transport costs and travel distance. However, DMs must be cautious while deciding on variables and constraints because some factors have high positive impacts to achieve certain objectives, whereas the same factor(s) affect other objectives to be accomplished. For example, *operational cost* and *supply unit* has a great influence on transporting maximum relief items, whereas they impact negatively on covering maximum demands. Hence, DMs should evaluate the applicability and impacts of those factors in their targeted context(s).

Fifthly, according to [26] and [45], instead of studying separately, all DPAs should be dealt with jointly and concurrently for effective disaster response. Therefore, by utilizing findings from this Delphi study and personal experiences, we have proposed an RD process model in Fig. 2. The model encompasses two distinct portions: information flow (denoted in solid arrows) and material flow (denoted in dotted arrows). To demonstrate processes more clearly, we assumed each DPA as an individual operational entity. The process starts by receiving (continuous) need information from the field that DMs analyze in the distribution centers. The assessed demand information is publicly forecasted immediately for informing neighboring communities to meet initial demand

Table 6. Correlational matrix of decision factors

*Please consult **Table 1 & 2** for identifying specific decision variables and constrains

Serial	Source	Rank	Decision Objectives	Cons-ensus	Highly correlated decision variables*		Highly correlated decision constraints*	
					Positive Correlation ≥ 0.3	Negative Corr.	Positive Correlation ≥ 0.3	Negative Corr.
1	Scientific literature	1	Distribution time **(minimize)**	Yes	rn(0.48), td(0.34), dt(0.29)	pc(0.15), trc(0.01)	ds(0.66), repc(0.53), trc(0.46), shc(0.4), ba(0.35), ihc(0.32), lf(0.29)	
2		2	Travel time **(minimize)**	Yes	ifc(0.45), td(0.4), tq(0.38), tt(0.38), rn(0.37)		lf(0.5), ra(0.4), trc(0.38), rc(0.3), td(0.3)	
3		3	Practical length of emergency route **(minimize)**	Yes	oc(0.43), tq(0.34), rn(0.3)	pc(0.13), bac(0.013)	trc(0.5), rc(0.4), shc(0.37), repc(0.35), lf(0.32), ihc(0.32), oc(0.31)	
4		4	Transport quantity **(maximize)**	Yes	oc(0.78), trc(0.57), ifc(0.45), stc(0.44), dt(0.34), su(0.32), tq(0.3)	det(0.2), rn(0.1), td(0.04), bac(0.002)	oc(0.6), shc(0.57), nsh(0.53), ba(0.53), rc(0.49), trc(0.45), lf(0.38), repc(0.34)	ds(0.12)
5		5	Coverage **(maximize)**	Yes	det(0.51), tt(0.47), rn(0.4), bac(0.31)	oc(0.06), su(0.01)	td(0.59), ra(0.47)	ba(0.18), shc(0.06), repc(0.03)
6		6	Penalty cost **(minimize)**	No	su(0.67), pc(0.58), tq(0.56), ifc(0.54), stc(0.49), oc(0.43), td(0.37), bac(0.32)	rn(0.09)	nsh(0.75), shc(0.62), ba(0.61), ihc(0.61), trc(0.52), rc(0.52), oc(0.41)	ds(0.04)
7		7	Total cost **(minimize)**	No	oc(0.71), trc(0.4), stc(0.4)	det(0.28), tt(0.23), rn(0.2), td(0.03)	trc(0.71), shc(0.6), nsh(0.4), ba(0.55), repc(0.58)	td(0.05), ds(0.002)
8		8	Number of distribution centers (DC) **(minimize)**	No	tq(0.58), det(0.55), su(0.52), tt(0.45), rn(0.4), pc (0.35), oc(0.34), dt(0.34), bac(0.32), ifc(0.33)		td(0.74), oc(0.58), ra(0.47), nsh(0.47), trc(0.47), ds(0.46), rc(0.43), shc(0.42), ihc(0.3)	
9		9	Travel distance **(minimize)**	No	pc(0.36), oc(0.36), trc(0.3)	rn(0.03)	ihc(0.5), trc(0.48), repc(0.36), lf(0.31)	
10		10	Resource cost **(minimize)**	No	trc(0.68), oc(0.67), su(0.6), stc(0.6), tq(0.4), td(0.4), pc(0.38), ifc(0.37)	det(0.23), rn(0.2)	nsh(0.71), oc (0.62), rc(0.62), trc(0.58), ba(0.58), shc(0.55), ihc(0.4), lf(0.35), repc(0.3)	ds(0.2)
11	Expert-preferences	1	Response plan **(maximize)**	Yes	v1(0.5), v2(0.57), v3(0.47), v4(0.79), v5(0.81), v6(0.55), v7(0.56), v8(0.44), v9(0.53), v10(0.46), v11(0.77), v12(0.59), v13(0.73)		c1(0.71), c2(0.8), c3(0.73), c4(0.79), c5(0.7), c6(0.78), c7(0.75), c8(0.75), c9(0.58), c10(0.47)	
12		2	Operational management **(maximize)**	Yes	v1(0.77), v2(0.46), v4(0.7), v5(0.59), v7(0.6), v8(0.34), v9(0.33), v11(0.65), v12(0.47), v13(0.66)		c1(0.35), c2(0.63), c3(0.53), c4(0.59), c5(0.6), c6(0.48), c7(0.48), c8(0.65), c9(0.44), c10(0.44)	
13		3	Central influence **(minimize)**	No	v2(0.45), v7(0.45), v11(0.33), v12(0.69)	v3(0.12), v9(0.19), v10(0.15)	c2(0.33), c5(0.4), c7(0.31), c8(0.5), c9(0.11)	c4(0.22), c10(0.08)

and to maximize coverage. The information on *social capital* is continuously assembled while preparing the responses by exploiting the decision factors evaluated in this research. By understanding the achieving objectives, DMs concentrate on utilizing necessary variables and constraints along with contextual ones. They consult and negotiate with other DPAs (if related) and plan for deployment.

RSC receives initial demand notes and establishes communication with the logistics hub or local market for procuring necessary items. Parallelly, RSC communicates with IM for updates of FL status and Sched for scheduling items to be transported and vehicles to be utilized. Then, Sched contacts with Transp and IM for finalizing the shipment(s) to be stored in FL or sent to the distribution centers (DC). As soon as deploying arrangement(s) is finalized, DC shares the distribution plan with the PODs. After dispatching relief items either directly from the procurement or the selected FLs, DC monitors the entire shipment(s) and continually communicates with responsible ones for updating the safety and security of the selected distribution network. Along with official informants,

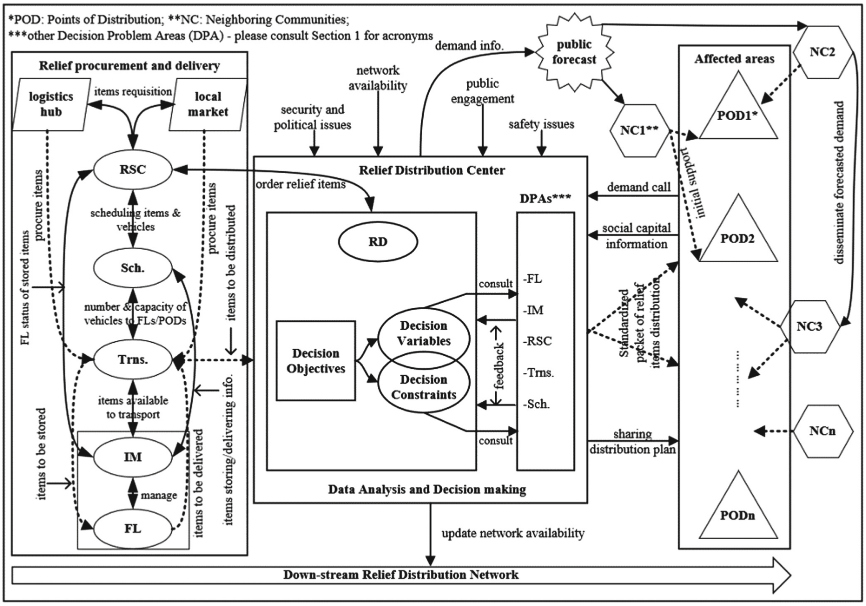

Fig. 2. The proposed relief distribution process model (inspired by [4, 28, 37])

DC may increase public involvement for a faster update on distribution networks (i.e., blocked road, collapsed bridge), political instability in the network, safety, and security.

While considering limitations, our study faced the typical weaknesses summarized by Hsu and Sanford [18]: low response rates and high time consumption. Our study also faced the challenge of participation discontinuing in future rounds despite participants being motivated by providing information about the survey topic, method, rounds, outcomes, and the overall research theme. Since we exploited emails to communicate with geographically dispersed experts, it was difficult to reach them as we got no indicate whether we were using the right addresses until participants replied. The conducted interviews were informative, but it was laborious for us to convert them to a questionnaire-like format.

After tackling all these difficulties, these summarized findings allow us to identify paths for future research. Decision factors learned from our work can be translated as system requirements for developing future IS artifacts (e.g., DSS), where the prioritization by the experts can form the basis of a typical *Must-Should-Could* assessment. The step following this article will be a design-oriented pragmatic approach that will effectively support rapid decision making for efficient relief distribution in large-scale disasters [30]. Our research will focus on proposing an operational ecosystem for RD by examining the influences that it receives from other problem areas introduced in Sect. 1. This operational ecosystem could feedback DSS to produce effective and efficient decision-making support.

6 Conclusion

Relief distribution is the core task of the humanitarian logistics operations. It depends on qualified decision-making in facility location, inventory management, relief supply chain, transportation, and scheduling. Except for a few of them, decision factors in relief distribution are shared by different problem areas. Thus, decision-makers need to know the decision objectives and how and to what extent decision variables and constraints influence them. In this article, we generated and evaluated two generalized sets of decision factors. The first one encompasses decision factors that researchers exploited in their objective functions and models to solve case-specific or scenario-specific relief distribution problems, whereas the latter one incorporates expert-recommended decision factors from the field. To provide decision-makers with manageable and comprehensive advice, we proposed a shortened and prioritized list based on expert ranking. However, for receiving the operational benefit, we still suggest decision-makers to keep tracking all the enlisted decision factors instead of searching the top-ranked ones only. As humanitarian operations are highly contextual and decision-makers face severe uncertainty in information gathering, processing, and implementation [31], we expect that the enlisted decision factors will support them to visualize and understand the changes and quickly identify relevant ones necessary for fast humanitarian relief distribution. We also proposed a correlational matrix to assist decision-makers with an understanding of the influential relationship between decision factors, so that they can select essential decision factors based on their respective contexts.

The findings in this research have various implications. Empirically evaluating the decision factors has extended the current body of knowledge on the RD process in large-scale sudden onsets. Based on our findings, we have contributed to the HumLog literature by extending the existing models to accelerate decision-making in disaster-like deeply uncertain events, where information is infrequent and incomplete. Our research findings, along with the proposed process model, will support field-based decision making in the down-stream of the humanitarian relief supply chain, as well as in the center. Moreover, it serves as an input to information system development to support decision-making. Additional research is needed to refine the findings and extend the process model to prototype and develop a decision support system to assist decision-makers with decision alternatives for actual implementation.

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