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Making decisions for effective humanitarian actions: a conceptual framework for relief distribution

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Abstract

Responding to a disaster encompasses a myriad of humanitarian actions; the ultimate and crucial is immediate relief distribution. Making effective decisions in chaotic disaster environment is always complex and challenging. Decisions made here are heavily influenced by the decisions made in several related problem areas such as facility locations, relief supply chain, transportation, scheduling, and inventory management. While each of these problem areas has its own set of decision factors, several of these factors are also common in multiple problem areas. These common decision factors offer both an opportunity and a challenge. The challenge is to balance the relative importance of a factor that is common between one or more problem areas—one factor that is considered vital in one area may have a lower priority in another area. The opportunity here is to develop a common framework that can help all problem areas to work together to achieve the main objective of effectively distributing essential relief goods among affected people. While the literature has studied individual problem areas and their decision factors, an integrated view showing the linkages between multiple problem areas is missing. In this paper, we propose such an integrative framework. Based on a systematic review of the literature, we first identified problem areas that are linked to relief distribution and then identified the linkages between these areas. We synthesized the findings into a conceptual framework and validated it through a panel of experienced field experts who work in relief distribution. We framed our refined framework as an information ecosystem of humanitarian actions where relief distribution resides at the core. Such a conceptualization will not only enrich the in-depth understanding of humanitarian domain, but also offer insights for developing computer-based decision support systems for relief distribution.

Keywords: Humanitarian actions, Relief distribution, Decision-making support, Decision factors, Operational ecosystem, Large-scale natural disaster

Introduction

The world is experiencing an increasing number of natural disasters. According to the Emergency Event Database (EM-DAT), there has been more than 6849 disasters from the beginning of the millennium (CRED 2019). Sudden and large-scale natural disasters put much pressure on governments and humanitarian organizations (Azmat et al. 2019) who respond to over 400 complex humanitarian emergencies every year (Clarke and Parris 2019). When a disaster occurs, affected people need quick relief through the provision of food, shelter, medicine, and clothes (Balcik and Beamon 2008). Thus, in the immediate aftermath of a disaster, all activities are directed towards the primary goal of relief distribution (Roy et al. 2012).

To get relief goods to the disaster areas, decision-makers need to be aware of multiple problem areas. Example of problem areas are facility location, inventory management, and transportation. These problem areas deal with decisions such as where facilities are

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located and how to access them, where to locate temporary facilities, how to organize the supply network to get relief goods from different facilities, how to transport these goods to the targeted disaster area, and finally, how to distribute them to the affected people (Howden 2009; Thomas and Mizushima 2005).

In each problem area, decision-making encompasses decision factors that comprise three elements

1. Decision objectives that related to optimize use of available resources. Examples are minimizing costs and distribution times or maximizing coverage area and beneficiary satisfaction,
2. Decision variables that need to be optimized to reach the objective(s). These variables are within the control of the decision maker. Examples include inventory cost and transportation quantity, and
3. Decision constraints that hinder the achievement of the objectives. These are seldom within the control of the decision maker. Examples are resource availability, number of available storehouses.

To illustrate how these concepts are tied together, let us take one problem area: transportation. Making decision in this problem area requires a decision maker to consider the three decision factors. The first is decision objective which can be to maximize coverage. To achieve this objective, the variables that decision-makers must consider are quantity and cost of transportation. These are within their control. What is not in their control are constraints such as availability of trucks and other relief vehicles, the condition of the roads etc.

If we focus on this one problem area by itself, an optimum decision can be made to achieve optimum relief distribution. The challenge lies when we look at another problem area that is tied to relief distribution: *facility location*, for instance. The decision objective here may maximize coverage. This may lead to locate facilities at locations favorable for replenishing inventory but may at the same time to long distances between facilities. This will of course act against the objective of the *transportation* problem area. This example also reveals another potential clash of objectives—with the *inventory management* problem area.

These examples starkly show the dilemma decision makers face in relief distribution: how to balance the different and often opposing priorities of each problem area? The humanitarian action literature has examined the different problem areas related to relief distribution in isolation. This has resulted in a fragmented view of the phenomenon and does not take into account that decision-makers in each of these problem areas need to collaborate with each other to arrive at a negotiated understanding of the situation.

Decision-making in relief distribution is thus a complex process. Moreover, decision-makers in this problem area face deep uncertainty due to incomplete or contradicting information, a highly unpredictable and dynamic disaster environment, and presence of multiple actors and stakeholders who use multiple methodologies and model alternatives (Comes et al. 2015; Rahman et al. 2019). Insufficient and fragmented information on identifying appropriate decision factors makes it difficult to generate alternative solutions to decision problems (Lempert et al. 2003). Yet, even with this insufficient understanding responders must make decisions to meet dynamic humanitarian needs (Spiekermann et al. 2015).

The literature has not ignored this problem. A variety of research streams has shed light on the humanitarian logistics area from different angels. While much insight has been gained, this also resulted in fragmentation: each problem area has become associated with a long, scattered, and unmapped list of decision factors. The number of decision factors increases correspondingly due to the contextual changes in operational fields, such as types of disasters, geolocations of disastrous areas and their infrastructures (Holguín-Veras et al. 2012; Kovács and Spens 2009). Azmat et al. (2019) proposed a shared understanding of important decision factors in associated problem areas since neglecting any of the affecting problem areas may disrupt effective decision-making for relief distribution. However, there have been few notable attempts that studied beyond individual problem areas and examined multiple problem areas together to explore how they are linked (see for example, Gutjahr and Nolz 2016). This integrated look is essential for optimal decision-making in relief distribution.

In conducting humanitarian relief operations in the field, decision-makers face complexity due to uncertainty in demand and supply, locations and durations of disasters, and unusual constraints (Altay and Green 2006; Lodree Jr and Taskin 2009). In addition to that many teams step into the scene in responding to a disaster by following their own ways or approaches, which sometimes complicate the situation (Bodaghi and Palaneeswaran 2016). They often do not effectively coordinate or cooperate with each other and thus bring several decision-making models and tools (see Özdamar and Ertem (2015) for a summarized list). The diversity in extant decision-making models causes delayed humanitarian responses to disasters due to mismatch in operational platforms as well as ineffective distribution of scarce or limited relief goods (Maxwell and Watkins 2003; Sangiamkul and van Hillegersberg 2011).

A challenge is to determine the decision-making aspects on which the linking between problem areas

should be made. Some research exists in this direction as well. For example, Gutjahr and Nolz (2016) investigated and listed optimizing objectives in problem areas to support humanitarian aid; however, their focus was on reviewing and discussing multi-criteria optimization methods. They did not address how these objectives are related and how they affect overall decision-making in relief distribution. An explication of both problem areas and some of the related decision factors were provided by Roy et al. (2012) in a general way without elaborating their interconnectivity or how the decision objectives, decision variables and decision constraints in each problem area affect other problem areas and relief distribution as a whole. With rare exceptions (e.g., Safeer et al. 2014), the literature is scarce on providing a holistic view of decision-making in humanitarian actions landscape, such as relief distribution.

Hence, we formulated the following research question to guide our research:

How do relevant problem areas together influence decision-making in relief distribution?

To answer this question, we took a multi-step and multi-method approach to develop an integrated and holistic conceptual framework. In step 1, we conducted a systematic literature review of humanitarian action literature focused on relief distribution. Based on the findings, we developed an integrated framework that shows how different problem areas in humanitarian logistics are connected. In step 2, we conducted a questionnaire-base study to validate and refine our framework through a panel of experts engaged in humanitarian actions in the field. Finally, we structured our refined framework as an operational ecosystem for humanitarian actions, where relief distribution activities played the central role.

The rest of the paper is organized as follows. In the section that follows, we briefly scanned the landscape of humanitarian logistics. We then present our systematic literature review in "Systematic literature review" section and results in "Results of the review" section. We present our induced framework in "The conceptual framework for relief distribution decision-making" section and its validation in "Validation of the operational ecosystem" section 6. In "Discussion" section, we discuss some critical findings along with limitations to our research and avenues for future research. "Implication" section includes implications for research and practice, whereas "Conclusion" section concludes the paper.

The humanitarian logistics landscape

Humanitarian actions, such as prevention, response, and recovery from disasters, and humanitarian logistics in particular, have received increasing attention from researchers and practitioners (Galindo and Batta 2013; Rauchecker and Schryen 2019; Wex et al. 2014). Making operational decisions in dynamic and volatile humanitarian context is not only complex but also challenging. Responders face difficulties with fluctuating relief demand, information and knowledge scarcity, distinct opinions from stakeholders, severe economic restrictions, and the interdisciplinary nature of the problem settings (Behl and Dutta 2019; Sheu 2010). Through an extensive literature review of humanitarian actions, Campbell and Clarke (2018) came up with a broader understanding of the nature and effective factors of decisions that practitioners make in real disasters. They suggested further research to make effective recommendations and guidelines for humanitarian decision-making.

Since selection of decision-making methods largely depends on the nature and context of the decision that varies based on the characteristics of the unfolding disaster (Lu 2017), Rahman (2018) suggested taking a pragmatic responding approach. In order to do so, identifying appropriate decision factors is necessary since inadequate understanding of decision factors leads to ineffective solutions (Gralla et al. 2016). Thus, existing decision-making methods need to be evaluated further not only to understand their applicability to the specific humanitarian problems but also to identify their appropriateness, extensivity, capability, and limitations in various disastrous contexts (Campbell and Clarke 2018). Decision-makers not only need to decide how to respond, but also need to make necessary adjustments in the on-going response (Hobbs et al. 2012). Hence, effective interacting channels (for communication, collaboration, and coordination) need to be established between decision-makers in different problem areas (Altay and Labonte 2014).

Through a survey of the humanitarian logistics literature, Peres et al. (2012) identified three problem areas in humanitarian relief distribution: *facility location, inventory management*, and *network flows and scheduling*. Based on interviews from field officers, Roy et al. (2012) added *transportation* and *relief distribution* to the list. Two additional problem areas that were tied to *facility location* and *transportation*, namely *epidemiology* and *repair* were identified by Gutjahr and Nolz (2016). In a later review, Besiou and van Wassenhove (2020) listed several humanitarian research topics in responding to natural disasters such as inventory location-allocation, network design, fleet management, forecasting and order planning, transportation, supplier selection, medical logistics. Along with identification of problem areas, a number of mathematical models have also been developed to help solve problems in these individual areas (see Behl and Dutta 2019 for a list of such mathematical

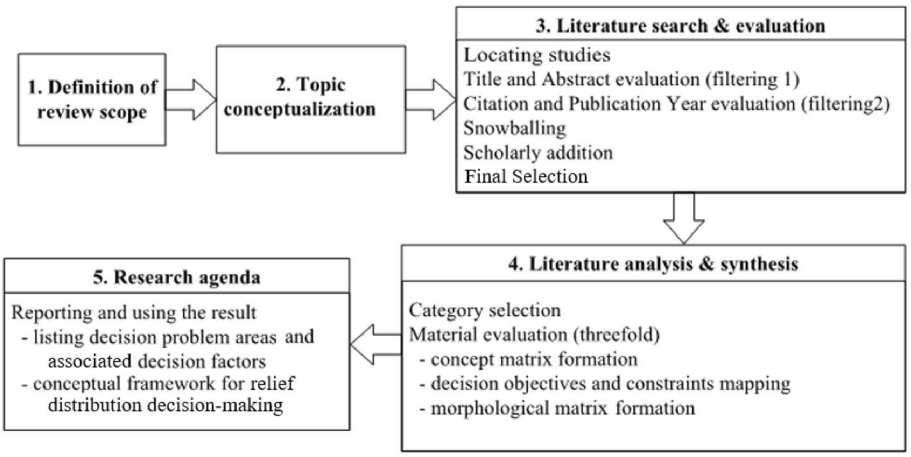

Fig. 1 The framework for this systematic literature review (adapted from vom Brocke et al. 2009)

Table 1 Categorizations in the literature review (adapted from Cooper 1988)

#	Characteristics	Description
1	**Focus**	Research outcomes, and the methods and theories used to produce them
2	**Goal**	Understanding how relief distribution decision-making is influenced by that of in other problem areas
3	**Organization**	Clustering articles according to their similarity in the conceptual development
4	**Perspective**	A neutral representation of the content regardless of subject area or outlet
5	**Audience**	General scholars and practitioners, especially in humanitarian actions
6	**Coverage**	Although all relevant sources were initially considered, only a selective corpus was finally analyzed

models). As useful as the focus on specific problem areas is, much less attention has been paid to examining the interconnectedness between them. Some researchers have stressed the importance of having a shared understanding of concurrent activities between problem areas (for example, Azmat et al. 2019; Roy et al. 2012). However, they have not provided any guidelines on how to do so.

The picture that emerges is that the literature on humanitarian problem-solving activities is fragmented with the focus on individual problem areas. People with similar background make decisions on achieving some specific operational objectives in a specific area without understanding how their decisions affect other problem areas. Developing mathematical models to aid decision-making in a specific problem area is commendable. To get a holistic perspective though, those mathematical models need to be examined for exploring how the decision factors in various problem areas influence each other. To explicitly focus on the interconnectedness between problem areas, we first conducted a systematic literature review which we present in the next section. The findings from this review were then analyzed to develop the conceptual framework for relief distribution.

Systematic literature review

We adapted the guidelines proposed by vom Brocke et al. (2009) for our systematic literature review. The framework comprises five sequential steps: (1) definition of review scope, (2) topic conceptualization, (3) literature search and evaluation, (4) literature analysis and synthesis, and (5) research agenda. The process is demonstrated in Fig. 1 and described in the following subsections.

Definition of the review scope

To identify our review scope and develop this research's foundation, we incorporated Cooper's (Cooper 1988) taxonomy in the review process. This exhaustive and systemized taxonomy involves categorizing six characteristics that are presented and described in Table 1.

Topic conceptualization

We conceptualized the topic for our systematic literature review in the humanitarian context based on the research question presented in the previous section. The research/review question was constructed by using the CIMO (Contexts, Intervention, Mechanism, and Outcome) logic presented in Deyner and Tranfield (2009). We aimed to support practitioners or decision-makers in relief

distribution in large-scale natural disasters (e.g., flood, earthquake, landslide, epidemic) rather than responding to daily emergencies (e.g., medical emergencies, policing, firefighting). Hence, a set of guidelines or framework would be needed to demonstrate influencing problem areas to relief distribution decision-making, their decision factors, and interconnections. we adapted the categorization decision-making support by identifying the problem areas, for which the models were developed and applied (or evaluated, validated, or assessed) afterwards.

Literature search

Our literature search and selection process had three major steps: study identification, study scrutinization and evaluation, and final selection. These steps are elaborated subsequently.

Study identification

To model a decision support framework for relief distribution, it was necessary to determine how the achievement of each decision objective is affected by various decision variables and constraints. We intended to examine the humanitarian literature for objective functions or decision support models tuned to operate the humanitarian actions during disastrous events. Thus, we expected to get a list of decision factors in three different categories: objectives, variables, and constraints. Hence, the first searching string was defined with a combination of keywords: [(objective function or model or decision support) and (humanitarian or disaster) and (supply chain)]. We also understood that rapid decision-making is hampered under deeply uncertain contexts and highly complex situations in humanitarian actions. Hence, we defined our second searching string: [disaster and {(short time (rapid)) or ((deep) uncertainty or complexity)} and {decision making or decision support or humanitarian logistics}]. Here, we avoided using synonyms of "disaster" since it is the ultimate destination of "crisis" and "emergency" if the events they encompass are not addressed correctly or managed early (Al-Dahash et al. 2016).

Based on the searching procedure described above, we extracted articles from two multi-disciplinary databases: Scopus and IEEE Xplore. Scopus is the largest repository for quality outcomes from multiple disciplines. It is easy to use and, thus, has an effect on research findings (Aghaei Chadegani et al. 2013; Boyle and Sherman 2006). In addition, IEEE Xplore incorporates a number of quality articles on developing objective functions to make optimal decisions considering different variables and constraints. A total of 1307 articles were extracted for further processing. Extraction details are demonstrated in Fig. 2.

Study scrutinization and evaluation

For maximum relevance, the titles and abstracts of the extracted articles were examined in the first round of filtering. Such activities were performed based on the set of inclusion and exclusion criteria (aligned with the research aims) presented in Table 2. To address the research question, we mainly considered only the disaster response related articles for further evaluation. After this rigorous initial filtering, 295 articles were selected for further evaluation in the second filtering.

Since the literature corpus was still large for full-text evaluation, we went for the second round of filtering. Identifying the trends of the publishing year associated with citation count was one way of further scrutinization since it provides indication to quality works (Tahamtan and Bornmann 2019). To do this, we examined the citation counts and publication years of the articles filtered in the previous phase (Bornmann and Daniel 2008). All contributions from 2017 were considered since they contained the most recent information on the research topic and, hence, had lower citation counts. Articles published before 2017 were clustered differently since they were already in the market for at least couple of years and thus, had higher citation counts. Detailed selection conditions are demonstrated in Fig. 2. After this second round of screening, the total number of sampled papers was reduced to 111.

To keep the repository up-to-date with important and influential contributions, we applied a reference snowballing (backward search) with author-mentioned important and relevant works. Instead of conducting a forward search of reference snowballing, we requested three experts from the humanitarian domain (academics) to scrutinize the resulting corpus and suggest missing but relevant literature. The entire process brought 27 more papers into the corpus. Thus, a total of 138 articles were selected for full-text evaluation.

Final selection

After discarding 21 inaccessible articles[1] from the 138 nominated ones, 117 papers were selected for full-text evaluation. The overall literature search and selection procedure is illustrated in Fig. 2.

Literature analysis and synthesis

After selecting the articles (mostly peer-reviewed and practice-oriented research papers), we organized them by identifying related categories to enable us to evaluate the corpus. To extract relevant information from individual articles and get a more comprehensive view, we adapted the categorization framework from Leiras et al. (2014).

[1] Unavailable authorized, full-text, and/or open-access PDF copy of the article.

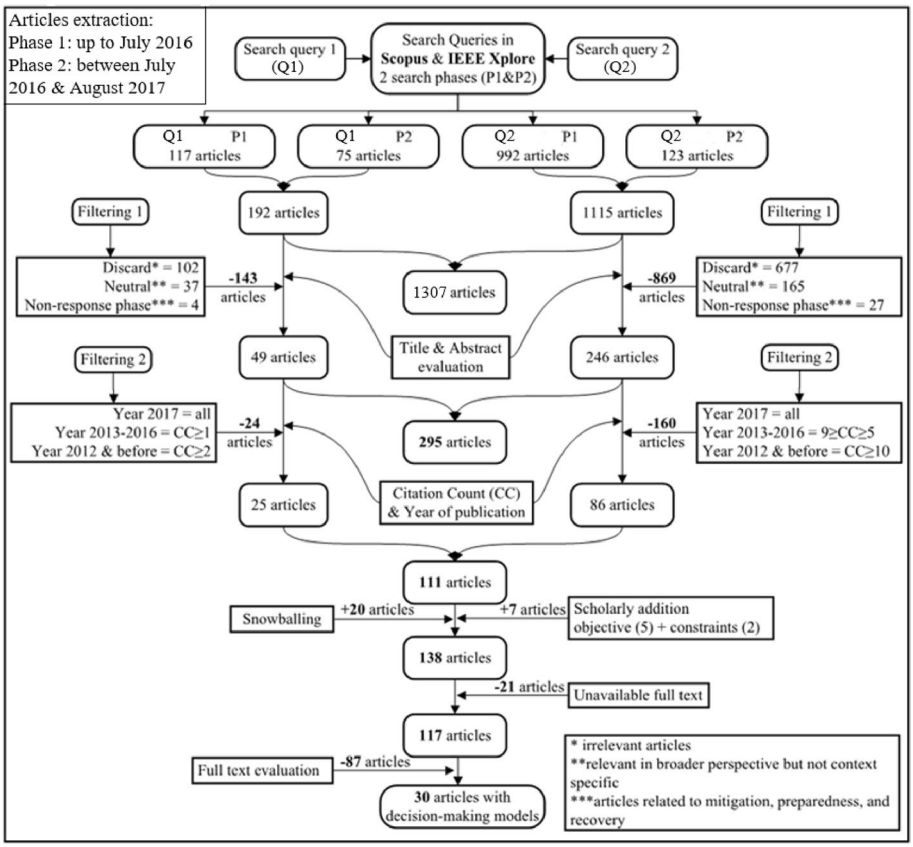

Fig. 2 Literature selection procedure

Table 2 Articles inclusion and exclusion criteria in the first round of filtering

#	Inclusion criteria	Exclusion criteria
1	Peer-reviewed articles in English: academic journals and conference proceedings; no temporal filtering	Non-English publications, duplicates, news, reports, etc.
2	Large-scale, sudden-onset, natural disasters	Regular crisis and emergencies
3	Several types of decision-makers (levels): operations/field-based and strategic	A generic focus or a sub-focus on humanitarian activities
4	Decision-making in humanitarian actions	Location and network planning
5	Humanitarian information management	Not proposing any information flow in humanitarian activities
6	Disaster response phase and discussions (e.g., preconditions, contexts, constraints) for the decision and coordination process	The other phases of disaster management: mitigation, preparedness, and recovery
7	Overall last-mile problems, e.g., relief distribution modeling, transportation, and scheduling	Evaluation or field study

This framework comprises of ten categories, which can jointly summarize individual papers. Since our review focus was to identify the ultimate list of the decision factors and then use it for identifying the relationship between decision objectives and constraints, we added these points as two new blocks into the framework. Figure 3 depicts the adapted categorization framework. We initially applied the framework to evaluate the 117 selected papers. We read each paper carefully and evaluated them before classifying them into a concept matrix.

In the next phase, we further inspected the concept matrix to identify articles that focus specifically on humanitarian actions during natural disasters, propose models, and list precise objectives and constraints. This inspection shortlisted 30 papers for in-depth evaluation to identify and map problem areas and their associated decision factors

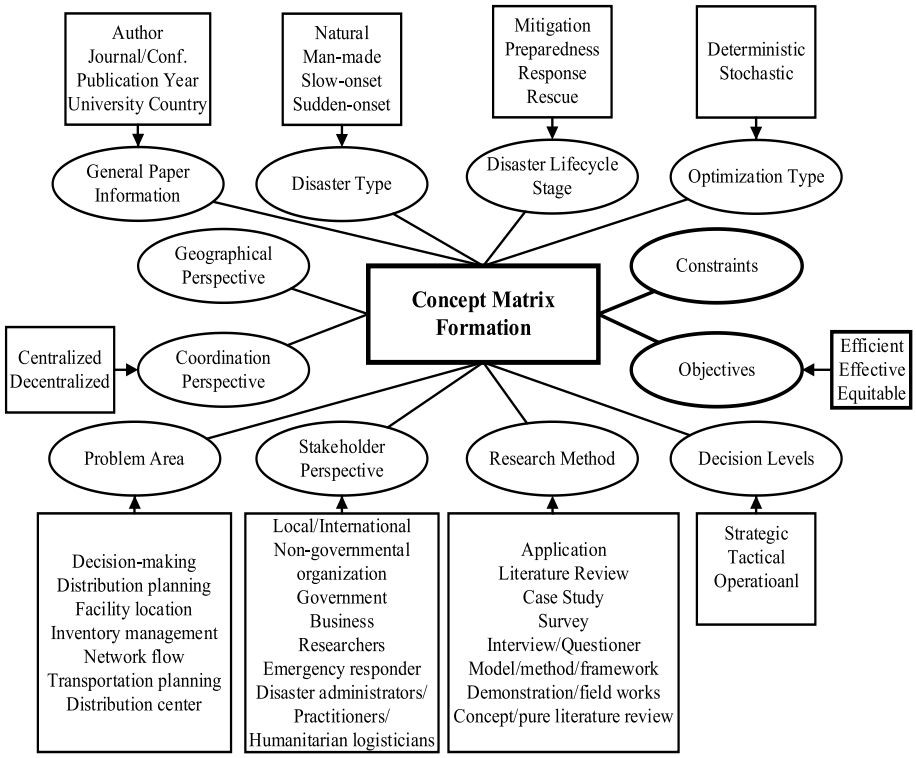

Fig. 3 The categorization framework (adapted from Leiras et al. 2014)

(objectives, variables, and constraints). To present the concept-centric analysis of the mapping, we formulated a morphological matrix in the final phase. It encapsulated a larger number of problem areas which have similar decision objectives, variables, and constraints. We further scrutinized the concept matrix by clustering conceptually similar decision objectives, variables, and constraints. Our analytical findings identified the problem areas that affect the operational decision-making in relief distribution in a holistic way.

Research agenda

When we completed the morphological matrix, it became easier for us to identify the problem areas and their associated decision factors, based on which the interconnectedness between problem areas could be determined. This provides us a basis to develop a conceptual framework that, after evaluation, can provide guidelines for supporting decision-making in relief distribution.

Results of the review

Our systematic literature review identified six problem areas in humanitarian operations

1. *Relief distribution (RD)* determines the effective distribution of relief goods according to the demand in a time-critical setting (Rahman et al. 2019; Roy et al. 2012).
2. *Facility locations (FL)* decides the number of relief bases needed and their optimal, easily accessible locations (Fereiduni and Shahanaghi 2017; Jabbarzadeh et al. 2016).
3. *Relief supply chain (RSC) that* manages quick product accumulation and processing for immediate response by optimally enhancing the capacity and volumes of product flows (Cao et al. 2016; Rahman et al. 2019).
4. *Inventory management (IM)* manages demand uncertainty by re-locating stocks and transporting relief items to depots (e.g., RD units) established in disaster areas (Fereiduni and Shahanaghi 2017; Peres et al. 2012).
5. *Transportation (Transp)* mobilizes relief goods (logistics, food, clothing, medicine, etc.) and emergency resources from one place to another within a shorter lead time by reusing vehicles to cover new routes within the same period in one attempt (Moreno et al. 2016; Roy et al. 2012).
6. *Scheduling (Sched)* focuses on optimized scheduling and assigning resources and personnel to specific tasks to achieve maximum equity or fairness in supplying relief items to the demand points (Peres et al. 2012).

Table 3 Identified problem areas, their conceptualization, and related studies[a]

#	Problem areas	Number of decision factors	Reviewed articles
1	Relief distribution	Decision objectives: 10 Decision variables: 13 Decision constraints: 12 Total decision factors: 35	Barahona et al., 2013; Chunguang et al., 2010; Gralla et al., 2015; Liberatore et al., 2014; Rancourt et al., 2015; Ransikarbum and Mason, 2016; Rottkemper and Fischer, 2013; Tofighi et al. 2016.
2	Facility locations	Decision objectives: 5 Decision variables: 17 Decision constraints: 11 Total decision factors: 33	Barahona et al., 2013; Cao et al. 2016; Fereiduni and Shahanaghi 2017; Han et al., 2010; Habib and Sarkar, 2017; Jabbarzadeh et al. 2016; Jha et al., 2017; Moreno et al. 2016; Tofighi et al. 2016.
3	Relief supply chain	Decision objectives: 6 Decision variables: 17 Decision constraints: 11 Total decision factors: 34	Chang et al., 2007; Fahimnia et al., 2017; Hu et al., 2017; Nagurney and Nagurney, 2016; Nagurney et al., 2011; Sheu and Pan, 2014; Zhen et al., 2015.
4	Inventory management	Decision objectives: 2 Decision variables: 9 Decision constraints: 11 Total decision factors: 22	Blecken et al., 2010; Fereiduni and Shahanaghi 2017; Kristianto et al., 2014; Rawls and Trunquist, 2010; Rottkemper et al., 2011.
5	Transportation	Decision objectives: 2 Decision variables: 6 Decision constraints: 8 Total decision factors: 16	Barbarosoğlu and Arda, 2004; Kristianto et al., 2014; Moreno et al. 2016.
6	Scheduling	Decision objectives: 3 Decision variables: 6 Decision constraints: 8 Total decision factors: 17	Han et al., 2010; Rolland et al., 2010.

[a] Please contact the first author for detail. Problem area specific decision factors are not included here

For each problem area we identified their relevant decision factors (decision objectives, the variables used, and constraints addressed). Table 3 lists the identified problem areas along with the number of encompassing decision factors. We also list the articles from which these factors were identified. Table 3 also illustrates that a total of 157 decision factors were identified composed of 28 decision objectives, 68 decision variables, and 61 decision constraints. These factors were distributed across the six identified problem areas. A close examination of these factors revealed that they were not always specific to a single problem area. We found that there were 63 decision factors that were shared across multiple problem areas. These factors comprised of 14 decision objectives, 28 decision variables, and 21 decision constraints. This revealed the interconnectedness between the identified problem areas which we show in Fig. 4.

The conceptual framework for relief distribution decision-making

Figure 4 shows how the identified problem areas are connected. The key question here is what is the strength of the connectedness between these problem areas? Based on the answer to this question, we developed a conceptual framework for relief distribution decision-making. As we have argued at the outset, at the center of this framework is relief distribution: the other five problem areas influence how decisions are made to distribute relief goods. Consequently, we calculated how strongly each of these problem areas are connected to relief distribution. To calculate the strength of the interconnectedness between two problem areas, we simply added the number of common decision factors between them. For example, the strength of relationship between relief distribution and facility locations was 18, calculated as follows: these two areas have three decision objectives, nine decision variables, and six decision constraints in common. Thus, the strength of the relationship is 18 represented as O(3)+V(9)+C(6)=18 in Fig. 5. It lists the calculations for the strength of the interconnectedness between relief distribution and the other five problem areas along with the graphical representation of the result. In it, the strength of the relationship is represented by the thickness of the arrows: the thicker the arrow, the stronger is the influence of that problem area on relief distribution decision-making.

Since the conceptual framework encompasses all the involved problem areas and their decision factors, we found it meaningful to present it as an operational ecosystem of humanitarian actions. We drew upon concepts of an information ecology developed by Nardi and O'Day (1998). Borrowing from biological ecology, they describe an information ecology as a complex ecosystem of parts and relationships, where the parts are diverse, and the system continually evolves. More importantly, the parts of the system co-evolve, and the co-evolution is driven by the interconnectedness between the parts. In using

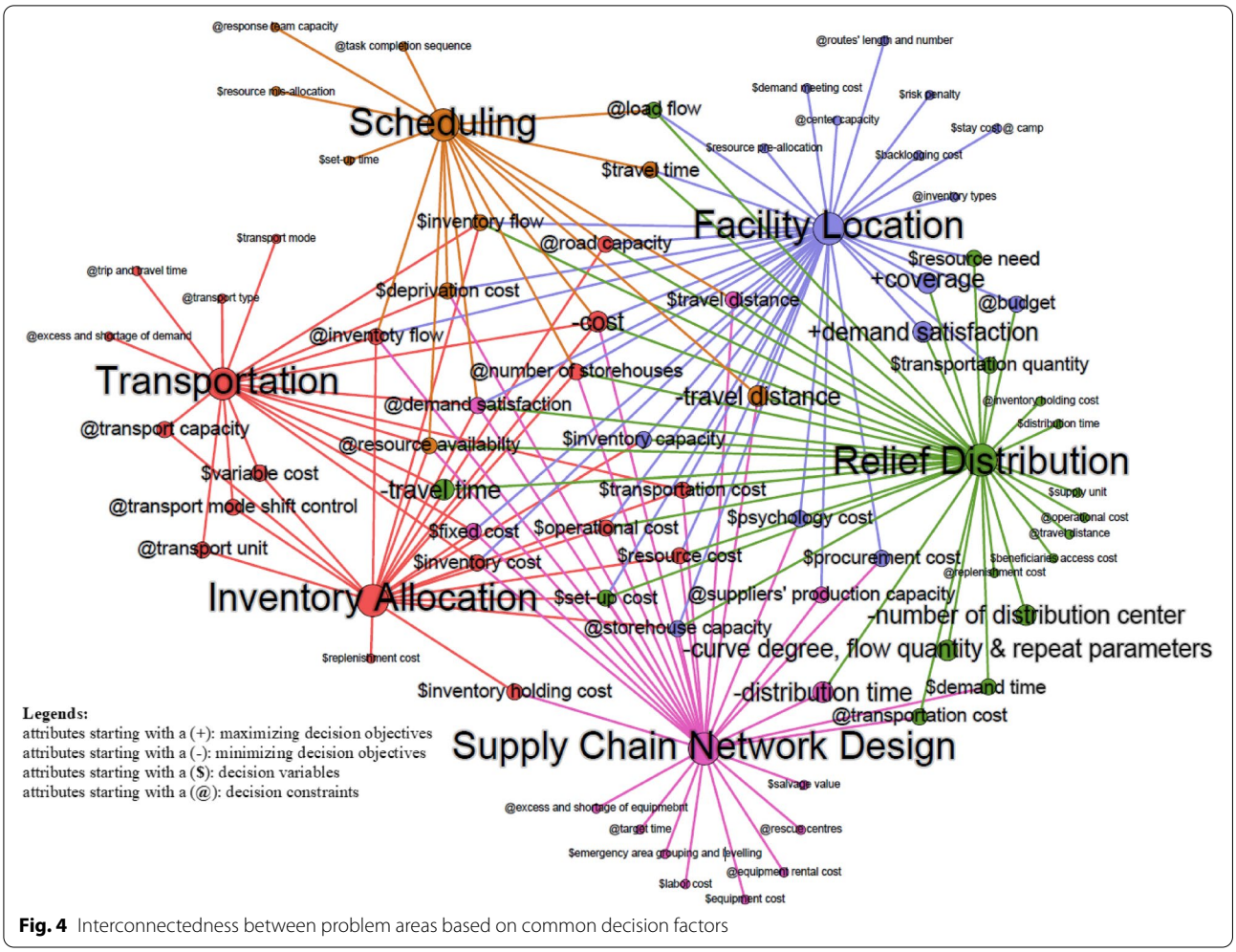

Fig. 4 Interconnectedness between problem areas based on common decision factors

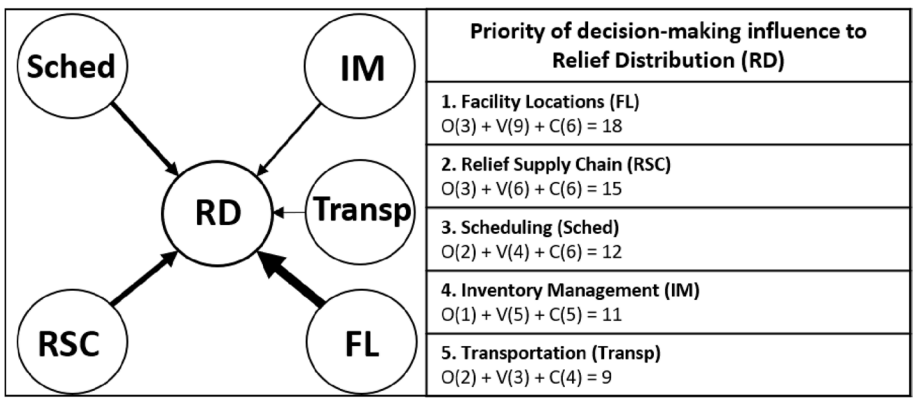

Fig. 5 The conceptual framework of relief distribution decision-making

the concept to explain how education was brought to remote mountain villages in Nepal through the Internet, Thapa and Sein (2018), page 8) described the usefulness of the information ecology as: "by looking at the interrelationships, interactions between the diverse species that makeup an ecosystem, we can get an insight to how they

coevolve and makes the system sustainable. We can also see how the system can fall apart […] An ecosystem is then a specific and more nuanced complex system. The elements of an ecosystem and the coevolving nature of the relationship between its diverse species provide this nuanced characteristic." The elements of the humanitarian ecosystem are the six problem areas identified in this paper (RD, FL, RSC, IM, Transp, and Sched) with relief distribution problem area at the core. The other five problem areas influence how relief distribution decisions are made. In keeping with the ecosystem metaphor as elaborated by Nardi and O'day (1998) and applied by Thapa and Sein (2018), these problem areas are the "species" of an ecosystem and *relief distribution* is the "keystone species". This is because if there is no need to distribute relief goods, there is no need for this particular ecosystem to exist. This is the definition of a "keystone species" that Nardi and O'Day (1998) made.

It is worth elaborating the co-evolution aspect of the ecosystem. As an example, the objective of minimizing *travel distance* is not only the objective of relief distribution problem area for deciding optimized distribution route to quickly provide survivors with relief goods but also the focus for other three problem areas: RSC, FL, and Sched. If a decision is made for achieving minimum travel distance only in RD without considering issues in other problem types, an overall ineffective result could be produced. That is because RSC, FL, and Sch. also have objectives that may not be achieved if travel distance is minimized. A similar interrelationship is revealed when we look at decision variables and constraints. Similarly, *facility locations* problem area focuses on maximizing *coverage* by establishing more warehouses nearby the affected areas, whereas relief distribution problem area targets achieving the same to reach more people/survivors. This intricate interconnectedness is captured well in the conceptual framework. It stresses that instead of studying problem areas separately, researchers are better served by developing an integrated approach that would support joint and concurrent activities among problem areas for deciding effective humanitarian relief distribution (Rekik et al. 2013; Roy et al. 2012; Vitoriano et al. 2011). Therefore, while planning an effective relief distribution, the common objectives should be balanced or negotiated so that each problem area also achieve its desired goals.

Validation of the operational ecosystem

To validate our literature-based ecosystem, we conducted a questionnaire-based evaluation with a panel of 23 humanitarian experts. The experts were humanitarian logistics researchers and practitioners with considerable personal experience in humanitarian actions, especially in relief distribution. We recruited the panelists through our personal networks, institutional affiliations, research groups' affiliations, and snowballing. Since we targeted experts with experience in recent disasters, all our panelists were mostly involved in humanitarian actions in the Indonesia earthquakes of 2018 and the Nepal earthquake of 2015. Table 4 presents the anonymized profile of each panelist.

The questionnaire we constructed had four sections. Section A contained questions related to the profiles of each respondent and their consent to take part in the panel and to allow us to process the data. The next three sections respectively contained questions related to the 10 decision objectives, 13 decision variables, and 12 decision constraints and asked the respondents to rate them. The questionnaire underwent several rounds of evaluation from six university professors, who have extensive experience in developing and utilizing survey questionnaires in multi-disciplinary research environments. A sample questionnaire (for decision-making objection in relief distribution) is given in Additional file 1: Appendix 1.

The final questionnaire was then sent to the 23 panelists through electronic mail. The questionnaire began with a concise description of the research motivation. To provide participants with a thematic understanding of the survey, the concepts used in the questionnaire was explained and essential instructions were provided. The experts were then requested to identify how the five problem areas (*FL, IM, RSC, Transp,* and *Sched*) affect each decision factor of *relief distribution*. Out of the 23 enlisted panelists, 16 evaluated the operational ecosystem for relief distribution decision-making. For a problem area to be considered essential for a specific relief distribution decision factor, 50% of the experts needed to agree on that. Based on the opinions by the panel, we refined the framework. The refined framework is shown in Fig. 6.

When we analyzed the panelists' opinions, we found that they unanimously (a) found the operational ecosystem to be a good depiction of the problem areas associated with relief distribution and (b) agreed that it was a useful basis for operational decision-making. However, we also found that they differed significantly (with literature-based ecosystem) in the strength and prioritization of the interconnectedness between the problem areas and relief distribution. The literature reported *facility locations* as the most influential problem area for relief distribution decision-making, whereas the panelists prioritized solving *transportation* problems for effective responses. According to them, the issues with *facility locations* have the least effect in relief distribution because these can be managed through mobile

Table 4 The validating panel of the operational ecosystem

Panelists' affiliation	Most recent experience	Years of experience	Category
P1. Logistics Cluster Coordination, World Food Program, Nepal	Nepal Earthquake 2015	30	Practitioner
P2. Nepali Army Crisis Management Centre, Nepal	Nepal Earthquake 2015	34	Practitioner
P3. Papua University, Indonesia	Several disasters	Unknown	Academic/researcher
P4. Universitas Pembangunan Nasional Veteran Yogyakarta, Indonesia	Merapi and Kelud volcanic disasters	11	Academic/researcher
P5. Yayasan Dompet Dhuafa Republika, Indonesia	Indonesia Earthquakes 2018	18	Practitioner
P6. Logistics Cluster Coordination, World Food Program, Thailand	Indonesia Earthquakes 2018	15	Practitioner
P7. AHA Centre, Indonesia	Indonesia Earthquakes 2018	Unknown	Practitioner
P8. AHA Centre, Indonesia	Indonesia Earthquakes 2018	13	Practitioner
P9. Kathmandu Living Labs, Nepal	Nepal Earthquake 2015	Unknown	Academic/researcher
P10. NetHope and ICE-SA, Iceland	Indonesia Earthquakes 2018	29	Practitioner
P11. Small Wars Journal, USA	Several disasters	26	Practitioner
P12. NetHope, Harvard Humanitarian Initiative Center for Humanitarian Data, Northwestern University, USA	Nepal Earthquake 2015	20	Academic/researcher
P13. WeRobotics, Switzerland	Several disasters	18	Practitioner
P14. Standby Task Force, USA	Nepal Earthquake 2015	5	Practitioner
P15. TU Delft, Tilburg University, and consultant for some NGOs and Civil Protection organizations, The Netherlands	Nepal 2015, Indonesia 2018	8	Academic/researcher
P16. UNOCHA, UN Human Rights, UNDAC, Switzerland	Typhoon Haiyan 2013	14	Practitioner
P17. Perkumpulan Lingkar, Indonesia	Jogja Earthquake 2006	12	Practitioner
P18. National disaster mitigation agency (BNPB) and Mohammodia disaster management, Indonesia	Indonesia Earthquakes 2018	12	Practitioner
P19. World Food Program, Nepal	August 2017 Floods	Unknown	Practitioner
P20. [1]	Several humanitarian fieldworks	Unknown	Academic/researcher
P21. Caritas Germany, Indonesia	Several disasters	Unknown	Practitioner
P22. WALHI Yogyakarta, SHEEP Indonesia, National WALHI, Sulteng Bergerak, Selat Sunda Bergerak, Indonesia	Indonesia Earthquakes 2018	12	Practitioner
P23. World Food Program, Indonesia	Indonesia Earthquakes 2018	11	Practitioner

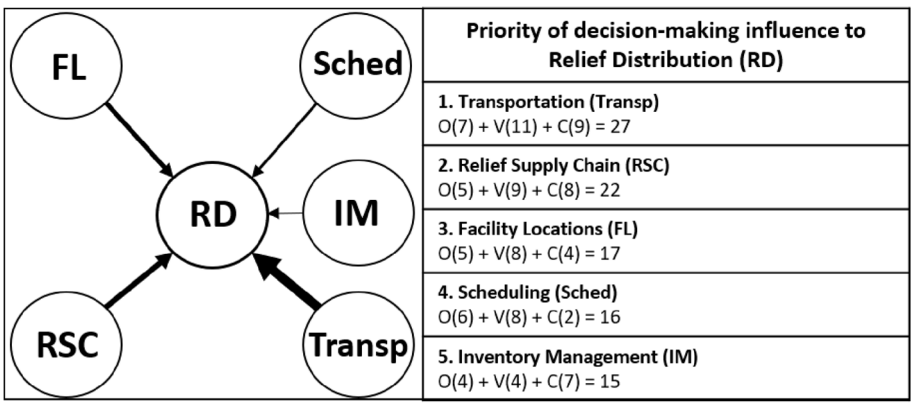

Fig. 6 The final operational ecosystem for relief distribution

warehouses, or by redirecting fleets to nearby places. By contrast, the operation becomes worthless if the relief goods cannot be transported to the survivors. Relief distribution like humanitarian action requires active and secure distribution networks. This finding echoes the findings of Safeer et al. (2014) who state that authorities always look for easily accessible points to set up *facility locations* for convenient *transportation.* These issues

Table 5 Comparison of influential priorities between literature and practice

Other problem areas	Literature-based (portrayed in Fig. 5)	Experts' preference (portrayed in Fig. 6)
	Rank	Rank
Facility locations (FL)	1	3
Relief supply chain (RSC)	2	2
Scheduling (Sched)	3	4
Inventory management (IM)	4	5
Transportation (Transp)	5	1

become crucial in the disaster environment. Interestingly, both rankings placed solving problems in *the relief supply chain* in the second position. Such a finding suggests that *the relief supply chain* should be planned immediately after solving problems with *transportation* or *facility locations* based on the operating contexts. The differences between the literature-based and experts' preferred ecosystems are summarized in Table 5.

Discussion

In this paper, we presented relief distribution as an operational ecosystem of interconnected problem areas through decision factors that they have in common. In our systematic literature review, we found only few studies that took such a holistic perspective of relief distribution (e.g., Gutjahr and Nolz 2016; Peres et al. 2012; Roy et al. 2012). While these studies discussed problem areas for decision-making in humanitarian relief operation, they did not delve deeply into the decision factors that are relevant for the problem areas. In addition to that, we identified the fragmentation in humanitarian literature—papers mostly concentrated on one problem area, or sometimes two. When the focus was on two problem areas, *facility locations* received the primary focus in most of the papers, and the other problem were depicted as supporting to achieve desired optimization in establishing facility locations. Consequently, some researchers in each problem areas stressed the importance of solving *facility locations* decision problems first and only then proceed to their intended decision-making goals on optimization (see, for example, Tofighi et al. 2016; Moreno et al. 2016; Fereiduni and Shahanaghi 2017). Other authors addressed *facility locations* issues through examining the *relief supply chain* problems (see, for example, Cao et al. 2016 and Jabbarzadeh et al. 2016). Through our validated ecosystem for *relief distribution*, we enhanced this discourse by taking an integrated and holistic perspective. For efficient and effective relief distribution, decision-makers must also consider achieving intended objectives in related problem areas. To illustrate such influences on relief distribution, decision-makers consider this scenario: if relief goods cannot be transported by reducing cost and travel time to the destination, humanitarian actions will be hampered by the delayed and costly response to the demand points. Therefore, the overall performance of humanitarian operations will be negatively affected.

Furthermore, gaining contextual understanding of the operating field is an essential part of relief-distribution decision-making. The practitioners in our panel ranked *transportation* as their top priority problem area while the literature ranked it lowest. Most of our panelists were from Nepal and Indonesia and had experience with relief distribution in two devastating earthquakes: the Nepal earthquake 2015 and the Indonesia earthquakes 2018. The topology of the affected areas was quite diverse: Indonesia is a country composed of over 1800 islands, while Nepal is predominantly mountainous. Accessing and distributing relief goods in these regions was much more difficult compared to countries with flatter terrains or those whose territories are contagious. Such geographical context explains why *transportation* is the most vital problem area for relief distribution. Additionally, the overall management of complex relief operations, for example in-country rules and regulations, always limits the international accessibility to the affected countries and thus, hinders the entire operational ecosystem for relief distribution that international responders provide. This understanding of the context will, to a great extent, influence how our framework is applied. As Campbell and Clarke (2018) and Lu (2017) elaborated, contextual understanding effects the selection of decision-making parameters and consequently, influence producing effective responses.

Like any research, our study has limitations. First, we analyzed the responses form the panel members without categorizing them. Had their responses been based on categories (e.g., academics, researchers, decision-makers, field practitioners), we could have gained a more nuanced understanding of what the groups emphasized. We did get some indication about how the literature (represented by the findings of our literature review) and practitioners (represented by our panelists) differ on the relative importance of the influence of problem areas to relief distribution. Future work aimed at closing this gap will improve the relevance of academic research for practitioners.

Second, we observed that some decision factors were listed in multiple categories (objectives, variables, and/or constrains), even in a single problem area. For example, while some researchers target achieving the objective of

minimizing *travel distance* for relief distribution, other researchers consider it as an attribute of decision variables and constraints at the time of selecting optimized distribution routes. In the same fashion, facility locations problem area focuses on minimizing *operational cost* for optimization, while accepting it as a decision variable at the same time. Interestingly, *relief distribution* problem area considers this factor as one of its unique operational constraints. Contextual problem settings may be the fundamental reason for this. To develop a more refined conceptual framework, more in-depth investigation is needed.

Third, most of our panelists came from two settings—the earthquakes in Indonesia (2018) and Nepal (2019). Although the specific contexts may have affected the final framework, the essence that problem areas influence relief distribution is unlikely to be fundamentally different had we included panelists from other settings. The relative strength of the relationships and the prioritization of the links would perhaps differ.

Fourth, we highlighted only the researcher and practitioner perspectives of the relief distribution challenge and did neither address the organizational structure of the response effort nor the multiple actors involved (e.g., government agencies, NGOs, and international organizations such as the UN). Additionally, among all three levels of decision-making (strategic, tactical, and operational), we concentrated primarily on the operational level in this article and left other two levels unexamined. This focus was a deliberate decision on our part to sharpen our scope, but it is also a limitation of our study. Since, effective relief distribution is highly influenced by organizational setups (Peres et al. 2012), future research should explore at which level the identified problem areas should be discussed and actuated. The findings from our article can serve as a foundation for such future research since it provides a holistic and inter-connected view of the affecting problem areas.

Implications

Our paper offers implications for both research and practice. For practice, we emphasized on having joint and concurrent activities for a successful humanitarian relief operation. By balancing decision factors among the connected problem areas, decision-makers in respective problem areas can achieve their intended operational objectives. Our conceptual framework can assist decision makers to make faster decisions on distributing relief goods by understanding how, and how far, different problem areas are interconnected in the distribution procedure.

At the same time, the multiple actors involved in any disaster relief operation present a governance challenge. As we stated above, we did not study the consequences of multiple actors in relief distribution operations. Different actors may have different priorities and may prefer various activities and thus, may take dissimilar actions to achieve similar goals. For example, international agencies may have the main objective of getting relief materials to the disaster-struck country and leaving distribution to authorities or NGOs that are local to affected areas. The latter may be acting on their own volition (many religion-based charity organizations fall in this category).

So, a coordinating mechanism is needed to achieve a common understanding of the emerging situations. For example, before initiating any operation at a selected relief distribution center, decision makers need to be updated about the recent deployments that were actuated in nearby distribution centers. Misaligned humanitarian support (in terms of relief items, quantity, targeted beneficiaries, etc.) may cause chaotic, inefficient, and ineffective relief distribution regardless of well-planned and well-equipped operations. Hence, the entire relief distribution decision-making process from planning to deployment should be robust, adaptive, and pragmatic (Gralla et al. 2016; Rahman 2018). Our framework can be the basis to set up a governing mechanism.

Furthermore, our framework can also be a basis to determine system requirements for prototyping and developing a computer-based decision support system to support decision makers in humanitarian actions. To support operational decisions, the computerized system should be provided with the essential system requirements (i.e., interconnected problem areas and their decision factors) along with adequate information from the environment (i.e., operations research, disaster response). It would suggest suitable decision alternatives by rapidly analyzing the demand and determining the necessary decision factors.

For research, our study enriches the humanitarian knowledge base, not only by extending the list of interconnected problem areas identified by Peres et al. (2012) and Roy et al. (2012), but also by incorporating associated decision factors in the ecosystem as a whole. Researchers on relief distribution can use these factors and the proposed ecosystem to offer models for assisting practical decision-making in the field.

Conclusion

Our study provides a set of salient decision factors and their encompassing problem areas. We highlighted the importance of examining the interconnectedness of problem areas and concurrent activities for successfully deploying relief operations. These concepts can be used to develop strategies for providing faster decision-making

support in relief distribution by bringing essential decision factors to decision-makers into attention. Through our proposed operational ecosystem, they can understand the depth of the interconnectivity of different problem areas in the distribution procedure. We specifically argued that relief distribution decision-making should be done in a concurrent and integrated manner. This holistic understanding s forms a basis for effective negotiations between decision-makers in the six problem areas—balancing objectives to gain a precise goal in combination. Thus, central authorities or a centralized governance mechanism can plan and execute effective humanitarian relief distribution activities by bringing decision-makers from all the interconnected problem-areas on to a shared operating platform.

Supplementary Information

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Additional file 1.

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