Supporting Humanitarian Relief Distribution Decision-Making under Deep Uncertainty

A System Design Approach

Mohammad Tafiqur Rahman

UiA University of Agder

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Evaluation Committee

Marcos R da Silva Borges, Professor
TECNUN – Universidad de Navarra, Spain

Trond Hammervoll, Professor
Østfold University College, Norway

Jaziar Radianti, Associate Professor
University of Agder, Norway

Supervisors

Tim A. Majchrzak, Professor
University of Agder, Norway

Tina Comes, Professor
University of Agder, Norway/
Delft University of Technology, Netherlands

This thesis is dedicated to

my beloved father, Mohammad Rafiqul Islam

and my beloved mother, Tafura Begum Islam.

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‘Ask yourself, “who” do you want to be. Not “what,” but “who.”’
-Arnold Schwarzenegger

Abstract

Disasters threaten society with widespread destruction of infrastructure and livelihood. For their survival, affected inhabitants depend on immediate humanitarian assistance from diverse organizations. During quick responses, humanitarian decision-makers (HDMs) act rapidly to distribute necessary relief goods, despite the deep, prevailing uncertainty that arises from scarce, conflicting, and uncertain information.

To support HDMs in humanitarian relief distribution (HRD) decision-making, humanitarian logistics (HL) researchers have developed various mathematical models. These models are, however, specific to disaster scenarios, and most of them are detached from the realities of the field since end-users (mainly practitioners) have been absent in the development process. When tested, these decision-making models were found to be capable of producing good results, but they have not been implemented in practice because of operational inconsistency or complexity (i.e., lack of user-friendliness). Therefore, humanitarian responders are still in need of support systems to assist them in determining effective HRD. A computer-based decision support system (DSS) can fill this need by providing necessary recommendations and suggesting decision alternatives. Hence, developing such DSSs is always the priority in HL.

However, in practice, HDMs generally utilize their experiences (on HRD deployment) for HRD decision-making (HRD–DM). They must deal with many situational facets, which sometimes cause difficulties in identifying and using essential factors for crucial decision-making under deep uncertainty (DU). To support HDMs in such situations, information systems (IS) artifacts play a vital role in covering many different dimensions, including information, social, and technology dimensions. Information dimensions involve acquiring and processing necessary continuous data (direct or indirect) for decision-making. Those data are analyzed to understand their meanings and relationships that may be used to identify and serve various needs. The social dimensions include individuals who participate in solving the targeted decision-making problem. Studying their interactions and relationships is important for receiving potential support in the problem-solving endeavor. Technological dimensions cover generating different decision rules for guiding computers to identify decision alternatives or make recommendations. By

identifying the decisions to be made, people set such rules and incorporate them into software systems or tools to provide adequate decision-making support.

Decision-making requires models of physical systems. This project, therefore, attempts to model an IS to profile decision-making requirements and their interconnectedness—thereby developing the envisioned DSS. To model such an IS artifact from the software development perspective, this dissertation covers only its *information* and *social* subsystems for the downstream portion of the humanitarian supply chain (HSC); the *technology* subsystem is isolated for future research.

The gap between IS research and humanitarian practices is the foundation for this project's main research question: "How can decisions in HRD be supported under DU?" To conveniently answer this overarching query, the main research question is divided into three sub-questions. The first identifies challenges in conducting this research: "What are the significant research challenges for operational decision-making in HL?" The second addresses tackling DU in decision-making: "How can DU be characterized in HL for HRD–DM?" The third elicits decision requirements: "What are the requirements for supporting HRD–DM?"

These questions are addressed in five research papers. Outcomes from these papers contribute to modeling the IS computer-based DSS to support HRD–DM. This system will provide decision-makers with necessary information concerning essential decision factors and clues about concurrent activities with other problem areas.[1] A Delphi panel of humanitarian experts (from academia and practice) empirically evaluated the decision factors for HRD–DM and their interconnectedness with other problem areas. The panelists were mainly involved in responding to the 2015 Nepal earthquake and the 2018 Indonesia earthquake.

Although DU is widely examined in environmental modeling or climate change, the proposed system adapts it to HL decision-making. Combining adaptive and robust decision-making approaches is recommended for making immediately implementable, real-time decisions. Thus, a limited (possibly predefined) number of decision-making process iterations should be applied within a shorter time frame.

[1] Problem areas are defined as the key functional areas identified by building upon the knowledge base in the context of humanitarian supply chain management research.

To establish the theoretical foundations of this multidisciplinary research, I examined and incorporated concepts from IS, HL, DSSs, and DU. After studying all the paradigmatic underpinnings of IS research, the pragmatic paradigm was chosen as the philosophical base for the project.

This dissertation mainly contributes to science by modeling a DSS design for HRD. By conceptualizing HRD as an operational ecosystem, it sets new IS design requirements for HL. Such a conceptualization identifies the decision factors encompassed in the interconnected problem areas. By examining these notions, researchers can understand how decision-making in other problem areas affects decision-making in HRD. These factors, in different combinations as situations demand, will help researchers generate different decision models for achieving various operational objectives. The conceptualization of DU can also be applied to multiple decision-making problems in HL research. Since the success of humanitarian operations (e.g., HRD) mostly depends on doable decision-making, this research argues for developing potential DSSs in task-oriented ways.

The proposals made in this dissertation also have practical implications. Practitioners can save decision-making time by consulting prioritized lists of decision factors. Faster decisions can be made if they are supported with the necessary information and with the essential decision variables and constraints for achieving specific objectives. Furthermore, the current research findings, not only provide decision-makers with an understanding of how problem areas are interconnected, but also facilitate concurrent activities by quantifying those influences. By engaging practitioners in requirements elicitation and analysis, this dissertation ensures their participation in system modeling and, thus, minimizes the gap between research and practice. The proposed IS will assist decision-makers in understanding, building, and using a DSS to distribute relief goods to the beneficiaries.

As with any dissertation, this project has several limitations, which also point to avenues for further research. The data have been mainly limited to two Asian countries belonging to similar societal, ethical, political, and economic infrastructures. Hence, the proposed IS may be biased by the understanding of the people in those regions. The Delphi panel was also relatively small, and its members varied in terms of expertise, responding mood, and time. Other cases and contexts can be considered in the future to evaluate the proposed system with a larger number of humanitarian experts. By outlining the recommendations of this Ph.D. research as a starting point, future multidisciplinary projects can be initiated to technologically develop the proposed DSS model for decision-making in HRD.

List of Abbreviations

APMO	Average Point of Majority Opinions
C	Decision Constraints
CC	Citation Count
CV	Coefficient of Variance
DAC	Data Analysis Capability
DBMS	Database Management System
DDU	Data Display and Use
DIS	Decision Information System
DM	Disaster Management
DMS	Dialog Management System
DRA	DSS Reference Architecture
DS	Data Stores
DSS	Decision Support System
DU	Deep Uncertainty
FL	Facility Locations
HDM	Humanitarian Decision-Maker
HL	Humanitarian Logistics
HRD	Humanitarian Relief Distribution
HRD–DM	HRD Decision-Making
HSC	Humanitarian Supply Chain
IM	Inventory Management
IS	Information Systems
mARD	modified Adaptive Robust Design
MBMS	Model-based Management System
MRQ	Main Research Question
NGO	Non-Governmental Organizations
NM	Normative Models
O	Decision Objectives
RQ	Research Questions
RSC	Relief Supply Chain
SAR	Search and Rescue
Sched	Scheduling
SE	Software Engineering
SLR	Systematic Literature Review
SRQ	Research Sub-Question
Transp	Transportation
V	Decision Variables
W	Kendall’s concordance coefficient

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1 Introduction

1.1 Scope

The twenty-first century has been called the century of disasters. The Emergency Event Database (EM-DAT[2]) has recorded around 7,000 devastating events, caused by either nature, humans, or both, from the beginning of the millennium (CRED[3], 2019). Natural disasters can be of two types: slow-onset and sudden-onset (Yilmaz et al., 2019). Slow-onset disasters include famine, drought, climate change, and environmental degradation, which gradually emerge over time, giving humanitarian decision-makers (HDMs) sufficient time to respond. On the other hand, sudden-onset disasters include earthquakes, cyclones, tsunamis, flash floods, and landslides, which affected around two billion people worldwide between 2008 and 2017 (IFRC[4], 2018c, p.168-169). In responding to such disasters, HDMs must take rapid initiatives, even when adequate information about the event and demand is lacking. Whichever terminology is used, disasters always cost lives, cause injuries, and lead to economic loss. By bringing such calamities, these widespread destructive events interrupt social activities in an affected area. Such disturbance further affects the area's social structure in ways that cannot be overcome with its available resources (IFRC, 2016). Furthermore, if the area in which a disaster occurs is densely populated, the losses (e.g., lives, societal, infrastructural, economic, health) increase enormously (Cavallo and Noy, 2009; Kunreuther, 1996; Lechat, 1979). Therefore, to survive these destructive events, affected people need immediate humanitarian support, and, thus, demand for such support has grown in recent years (Besiou and Wassenhove, 2019).

Because they have varying attributes and are caused by different events, disasters are complex (Chan and Comes, 2014). Each time they arise, disasters of similar type show specific characteristics that were not previously experienced (Ashinaka et al., 2016; Campbell and Clarke, 2018). Since the time, place, and extensivity of disasters vary (Baharmand, 2018), HDMs face difficulties in disaster response, among which effective decision-making being one of their most critical challenges. HDMs struggle to identify required actors and factors in their response

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[2] Emergency Events Database (www.emdat.be)

[3] Centre for Research on the Epidemiology of Disasters (www.cred.be)

[4] International Federation of Red Cross and Red Crescent Societies (www.ifrc.org)

operations (Chan and Comes, 2014). Humanitarian logistics (HL) researchers have reported that it is necessary to study the interconnectedness between these influencing actors and factors (Campbell and Clarke, 2018; Darcy and Hofmann, 2003; Newman et al., 2017). Since last-mile humanitarian relief distribution (HRD) is the ultimate goal of any disaster response operation (Roy et al., 2012), Azmat et al. (2019) indicate that it is imperative to understand how different actors in the affected areas share (or use) similar factors.

On the other hand, HRD decision-making (HRD–DM) involves, not only identifying relief goods (type, quantity, priority, etc.), but also deciding where to deliver these goods and at what time (Campbell and Clarke, 2018). HDMs must know how complicated the targeted problem is, what the degree of uncertainty is, and what implications their choices will have (Cioca and Cioca, 2010). They should also be capable of dealing with a large amount of data, limited resources, and the unpredictability of disasters and post-disaster situations (Sahebjamnia et al., 2017). Additionally, decisions must be made over time since the arrival of new information may be profoundly influential. An interactive decision support system (DSS) can support HDMs to tackle these operational challenges and complexities in disaster response. Sahebjamnia et al. (2017) reveal the urgency of developing necessary DSSs for humanitarian responses but report that vital decision factors (i.e., decision objectives, variables, and constraints) are scarcely identified for such development. To fulfill the necessary decision requirements, researchers must work together with practitioners—incorporating their values and keeping them onboard until the system is developed and implemented (Coletti et al., 2017; Lynch and Gregor, 2004). By incorporating essential decision factors in the physical system (i.e., DSS), various decision alternatives can be recommended. The effectiveness of such a DSS depends on how well it supports identifying essential decision factors and allows them to be used to select alternatives based on practitioner realities (Widera and Hellingrath, 2016, p.341). Chosen decision alternatives must then be implemented and managed to achieve efficient HRD by using the available resources in the best way.

DSS development traditionally consists of two phases: system design (modeling) and system building (computer hardware and software) (Vazsonyi, 2013, p.387). This dissertation focuses on system design to identify an organized set of practices and procedures, which the actual DSS should follow when built. In doing so, an extensive study is conducted in this information system (IS) research. This study also identifies the decision factors (as system requirements), information flows, and material flows vital to the success of an operational DSS (Alshibly, 2015). To assist HDMs with decision alternatives, the proposed DSS model will exploit various information flows associated with disaster management (DM)[5] and HRD[6] in HL[7]. It will fetch necessary information from DM to identify essential decision parameters (problem areas and their associated decision factors and interconnections) and from HRD, concerning supply and demand of relief goods. The acquired data will then be analyzed and shared to maintain material flows toward the demand points, thereby distributing relief goods as required. Processed data can be warehoused for future use. Thus, conducting last-mile HRD contributes to DM and effectively responds to the targeted disaster (Ortuño et al., 2013). Figure 1.1 articulates an abstract view of such operations. Although decision factors are mostly elicited from the literature, experts' suggestions are also enlisted from a group of panelists. These panelists, who evaluate the decision factors, mainly participated in responding to the 2015 Nepal earthquake and the 2018 Indonesia earthquake. Although contextualized in developing Asian countries, the proposed DSS model will be applicable to other regions after achieving necessary modifications.

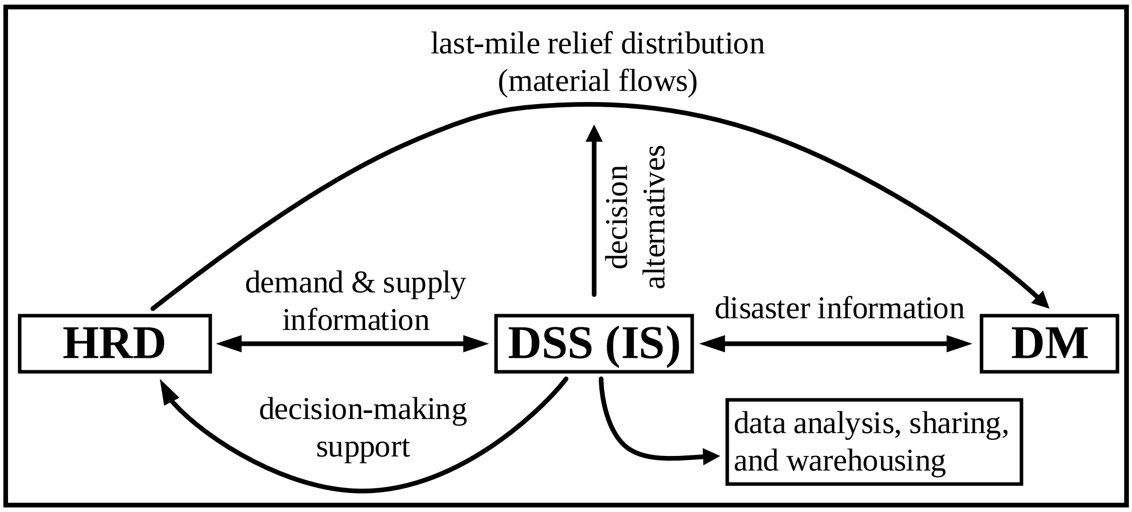

Figure 1.1: DSS support for humanitarian responses in DM

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[5] DM organizes and manages resources and responsibilities to deal with all essential humanitarian aspects before, during, and after disasters (Alexander, 2015). It involves planning for mitigation, preparedness, response, and recovery to reduce all negative disastrous impacts (Moe and Pathranarakul, 2006).
[6] HRD determines the effective distribution of relief goods according to demand in a time-critical setting (Rahman et al., 2019).
[7] HL plans, implements, and controls materials and information flows to maintain supply and demand for lessening the human suffering resulting from disasters (Apte, 2010). It includes a wider range of operations, such as preparation, planning, design, procurement, transportation, inventory management, warehousing, distribution, tracking and tracing, importation and exportation, and customs clearance (Agostinho, 2013; Thomas and Kopczak, 2005).

1.2 Background

Natural disasters are unavoidable and untraceable sudden-onset environmental calamities. In such situations, supporting affected people with humanitarian relief goods is always a difficult task. From relief goods procurement to distribution, humanitarian responders perform many decision-making activities. For example, they must decide which relief goods to procure, where to store them, how to transport them to the demand points, and how to distribute them among beneficiaries. Unlike commercial supply chains, humanitarian supply chains (HSC) suffer from incomplete, irrelevant, and sometimes excessive disaster data (Carver and Turoff, 2007; Comes and Van De Walle, 2016). These data must be formatted appropriately and managed efficiently so that effective decisions can be made for rapid humanitarian responses (Comes et al., 2015a; Thompson et al., 2006). To do so, Carver and Turoff (2007) suggest human-computer interaction, in which computer systems provide analytical support to decision-makers, helping them make suitable operational decisions. Human use of computer hardware and software technologies to produce essential information for decision-making is called a DSS (Alshibly, 2015). Such systems generate timely, integrated, accurate, and useful information for practically solving different managerial problems (Al-Mamary et al., 2014). Although decision-making highly depends on users' needs, the specific application contexts, and time, Power (2013) argues that such supporting systems should be interactive, flexible, and adaptive. They should offer easy-to-use interfaces, so practitioners can more readily use the related data and their intuitions to make the ultimate decisions.

Decision-making is one of the main tasks of humanitarian operations (Newman et al., 2017) because it directly impacts the humanitarian actions and, by extension, the affected communities (Schätter et al., 2017). Research on these topics, although vital, has received insufficient academic attention (Campbell and Clarke, 2018). Behl and Dutta (2018) conclude that HL literature only provides some topic-specific understandings of individual problems but, as yet, offers no comprehensive study. Additionally, the existing mathematical DSSs are not systematically operated in dynamic or multiple disaster scenarios (Kimeli, 2016). They are mostly static, informal, emergent, ad-hoc, and reactive (Campbell and Clarke, 2018; Schätter et al., 2017). Newman et al. (2017) report limited successive evidence of practical DSSs in their extensive review. They have also indicated a lack of stakeholder participation in developing and using DSSs.

On the other hand, due to the diversity of disaster contexts and regional characteristics, finding one best decision-making approach is impractical. Researchers, thus, generate case-specific models, which mostly rely on a fixed dataset (to feed the models). Hence, Ivanov and Knyazkov (2014) and Kimeli (2016) argue for a long-term adaptation of existing DSSs, but the review by Newman et al. (2017) reveals that very little adaptation of this sort is taking place. Therefore, to solve such decision-making problems, extensive multidisciplinary research is necessary (Ashinaka et al., 2016; Campbell and Clarke, 2018). When modeling such an approach, researchers should consider varying degrees of operational uncertainty and timing.

In practice, decisions are made based on decision-makers' hard-earned, previous experiences (Leseure et al., 2010). To efficiently improve humanitarian actions, HDMs cognitive decision-making processes must be complemented by technology-supported information (Leseure et al., 2010; Wallace and Balogh, 1985). A computer-based, well-structured, and flexible DSS is necessary for assisting humanitarian responders' operational decision-making (Ashinaka et al., 2016; Comes et al., 2011; Yates and Paquette, 2011). Conceptualizing this, Cioca and Cioca (2010) state that DSS is a distinct class of IS, designed to propose practical solutions to targeted problems by exploiting data from different sources, such as sensors, social media, operating fields, volunteers, etc. When analyzed, these data will assist HDMs, not only in understanding what to support (demand), where to support (infrastructures and accessibilities), and how to support (resources) but also by identifying the actors involved in HRD. An advanced IS can be designed to collect essential data from selected sources in different humanitarian contexts and analyze them to identify requirements for building the required DSS (Comes and Van De Walle, 2016). Such findings can subsequently be shared with appropriate channels (or actors) for rapid, but efficient and effective, decision-making (Howden, 2009; Tatham and Spens, 2011).

Although IS is widely used in business and science to support decision-making (Arnott and Pervan, 2014; March and Hevner, 2007; Montgomery and Urban, 1970), it is sparsely employed in DM (Bharosa et al., 2009). Magnusson et al. (2018) claim that the current lack of systematic analyses concerning users' needs could be the reason for the rare, but slowly advancing, development of IS for DM. Ahmad et al. (2012) support these claims by highlighting the communication gap between system development (researchers and developers) and practice (HDMs).

Both parties have reported challenges and/or inaccessibility to one another for data collection and research results acquisition, respectively (Kunz et al., 2017). To process disaster data and support disaster managers in their decision-making, Belardo et al. (1984) have adapted (from Montgomery and Urban [1970]) an integrated decision-information system (DIS). According to Belardo et al. (1984), effective decision-making largely depends on the relevant data, analysis, and cognitive capabilities of decision-makers. They also emphasize the dependency among decision factors, as well as meaningful data formats for reducing damage surprise and decision-makers' stress. Wallace and De Balogh (1985) have enhanced this conceptual DSS model by applying three different management systems (the dialog management system [DMS], the model-based management system [MBMS], and the database management system [DBMS]) to the model's four main components (technology for display and use, data analysis capability, normative models, and databank). Their final model is conveyed in Figure 1.2, where the functionalities are named to improve readability. With sufficient modifications, this dissertation further develops this model to design the intended DSS for supporting operational decision-making in HRD (Chapter 6).

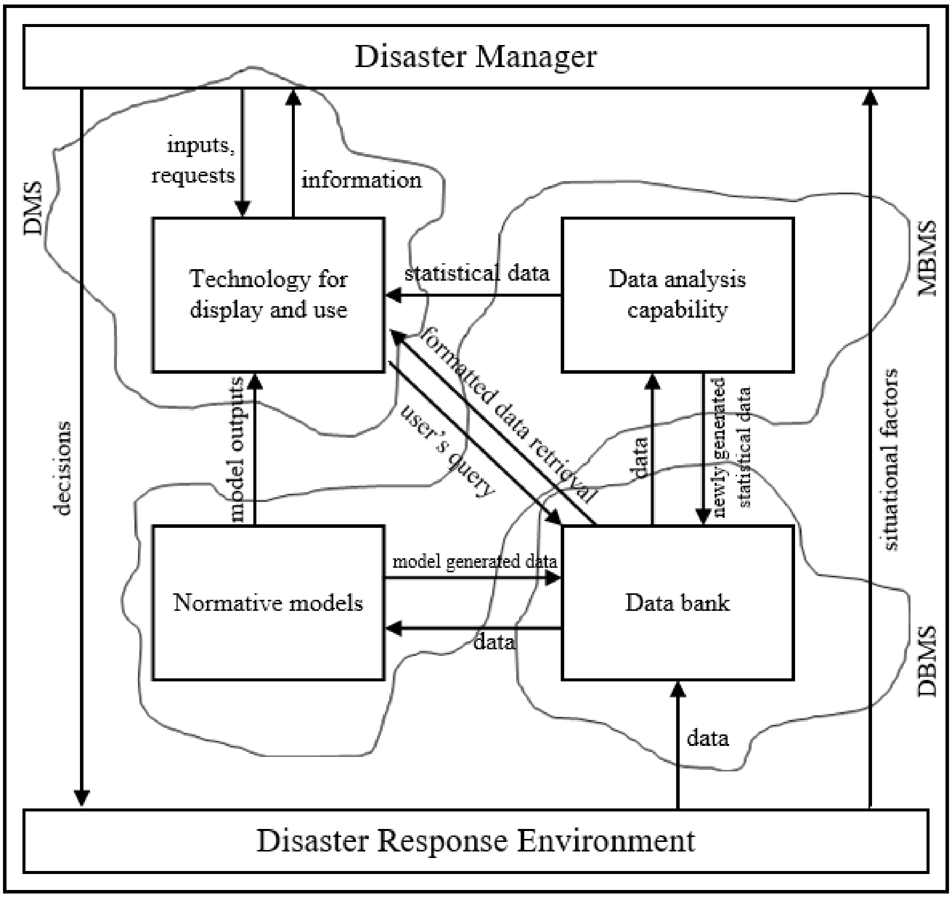


Figure 1.2: DIS for DM (adapted from Belardo et al. [1984], Montgomery and Urban [1970], and Wallace and De Balogh [1985])

1.3 Motivation

The research reported here began with a historical case: the response to the super cyclone Sidr. It hit the Bangladeshi coast on November 15, 2007, and left around 15,000 people dead (ADRC[8], 2019). I, along with a few university friends, operated a relief drive (from procurement to distribution) for Pirojpur, one of the four severely affected coastal districts of Bangladesh (MFDM[9], 2008; IFRC, 2010). Delivering relief goods to the affected areas was difficult and challenging as road-links were washed out and blocked in some regions by rubble (Hossain et al., 2008). As a small, standalone, ad hoc volunteer response team, our group faced many challenges in this operation. We had no clue about the needs, demand points, transportation, or logistical arrangements. By getting some informal supports (through personal contacts) from the Bangladesh Army, the team distributed clothing, blankets, dry food, and some primary medicines to the affected people. The frequent natural calamities in my native land, as well as the 2007 response activities for Sidr, inspired me to conduct this research. This type of research is essential for facilitating faster humanitarian responses, especially in populous countries (e.g., Bangladesh, Indonesia, Nepal), whose troubles are compounded by rapid and unplanned urbanization.

The population densities of areas affected by disasters cause enormous suffering, not only to the affected people but also to the humanitarian responders. Poor communication and accessibility infrastructures in these areas also hinder humanitarian decision-making at the right times and in the right places. Delays in such operations result in increased suffering and higher death tolls. Due to the lack of proper integration, technological advancements, IS, and logistics, HDMs still do not receive adequate decision-making support for better disaster responses (Baharmand, 2018). Although identifying critical decision factors (not just specific to models, but overall) and their associated problem areas is vital for providing such support, a collaborative study has not yet gained research focus (to the best of my knowledge).

As presented and discussed in the Euro Hope Mini-Conference 2019, HL lacks adequate systematic support for making response activity decisions (Benaben and

[8] Asian Disaster Reduction Center (ADRC-www.adrc.asia)

[9] Ministry of Food and Disaster Management (MFDM)

Lauras, 2019). Benaben and Lauras (2019) looked for operational DSSs developed in this domain since 2006 but reported that there were none. However, along with numerous scenario- and problem-area-specific (mathematical) research models, many task-specific initiatives can be identified in practice, including Sphere Project,[10] HXL,[11] MIRA,[12] Cash and Vouchers,[13] and ESUPS,[14] to name a few. The Sphere project focuses on ethical and legal issues to ensure that affected people can enjoy their right to live a protected life with dignity. MIRA emphasizes needs assessment with some standard operating procedures, whereas ESUPS promotes communication and coordination for pre-positioning relief goods. HXL focuses on data processing and interoperability, whereas the Cash and Vouchers initiative provides monetary, commodities, or service support to the affected people. Although such initiatives help individual wings of critical decision-making, DSSs are still needed to give practitioners holistic decision-making support with essential decision alternatives and/or useful recommendations. Such a physical system requires (machine) learning procedures to feed its model with the necessary information, as well as decision rules guiding computers to generate prioritized decision alternatives. However, to achieve the required information, the system must still be able to analyze a large amount of disaster data systematically and rigorously (Papadopoulos et al., 2017; Van den Homberg et al., 2018). Such achievements will assist HDMs in managing both familiar and unknown situations to make effective decisions by gathering inputs from the extant circumstances (Benaben and Lauras, 2019).

All these understandings motivated me to study the influence of the problem areas in HRD–DM. The associated problem areas must operate concurrently for effective HRD (Roy et al., 2012). Such realization indicates the necessity of studying the decision factors encompassed in those problem areas and understanding how multiple problem areas use (or share) similar factors for individual decision-making. These decision factors were, in this research, identified by systematically reviewing the decision/optimization models published in the academic literature and

[10] Sphere: https://spherestandards.org/about/
[11] The Humanitarian Exchange Language (HXL): https://hxlstandard.org/
[12] Multi-Cluster/Sector Initial Rapid Assessment (MIRA): https://www.humanitarianresponse.info/en/programme-cycle/space/document/mira-manual
[13] Cash and Vouchers: https://ec.europa.eu/echo/files/policies/sectoral/ECHO_Cash_Vouchers_Guidelines.pdf
[14] Emergency Supply Pre-positioning Strategy (ESUPS): https://esups.org/

later validated by a panel of humanitarian experts. Furthermore, to enhance decision-making support in HRD, I have considered conceptualizing deep uncertainty (DU) in the proposed model and tackling it by producing decision alternatives.

1.4 Research Questions

When I began this study, the problem was framed around the decision-making complexities I experienced during the 2007 HRD operation for the Sidr super cyclone. My observations and experiences during that disaster inspired me to investigate effective ways to provide rapid decision-making support to disaster response HDMs. Hence, the main research question (MRQ) for this dissertation became:

MRQ: How can decisions in HRD be supported under DU?

Three sub-research-questions (SRQs) were formulated to answer the MRQ. As a starting point, I aimed to learn the breadth and state of HL research by exploring related information and literature. I especially emphasized decision-making problems in HRD operation and, thus, stressed identifying research challenges to designing an interactive DSS in the HL domain. Hence, the first SRQ was formulated as:

SRQ 1: What are the significant research challenges for operational decision-making in HL?

SRQ 1 identified three salient research points that must be addressed while modeling the envisioned DSS. These challenges were: DU, HL modeling, and decision analysis. They are introduced, with short descriptions, in section 5.1, but they are fully elaborated in Paper 1. The remaining two SRQs address these tasks to build different parts of the process and complete the system model.

Tackling DU in HRD–DM is the initial challenge identified in SRQ 1. To characterize this concept in HL problems, I studied DU tackling techniques, which were mostly available in other disciplines (e.g., climate, business, management, etc.). Since they are computationally cumbersome and time-consuming, none of these techniques is directly applicable to HRD–DM. Therefore, to discuss the implication of DU in different HL problems and propose an approach for addressing it in HRD–DM, the second SRQ was framed as:

SRQ 2: How can DU be characterized in HL for HRD–DM*?*

The other two research challenges identified in SRQ 1 (rapid HL modeling and decision analysis for functional responses) were addressed together in the third SRQ. Initially, to find appropriate research methods or tools to solve the decision-making problem in HRD, I examined the philosophical underpinnings of the HL research domain. Afterward, a rigorous and systematic study was conducted to identify the operational ecosystem of HRD by integrating problem areas and their associated decision factors in humanitarian operations. Finally, by analyzing and validating the components of the ecosystem, the requirements were elicited for the intended DSS model. Therefore, to cover all these outcomes, the third SRQ was formulated as:

SRQ 3: What are the requirements for supporting HRD–DM?

Finally, the SRQs were solved, step-by-step, in research articles included in the dissertation (Papers 1–5). Together, they answer the MRQ to develop the intended DSS design. The research articles support each other to determine every finding and, thus, strengthen their contributions to the research outcomes. The relationships between research questions (RQ) can be visualized in Figure 1.3 and Figure 5.1. Figure 1.3 also summarizes this research's overall development process that is elaborated in Chapter 4.

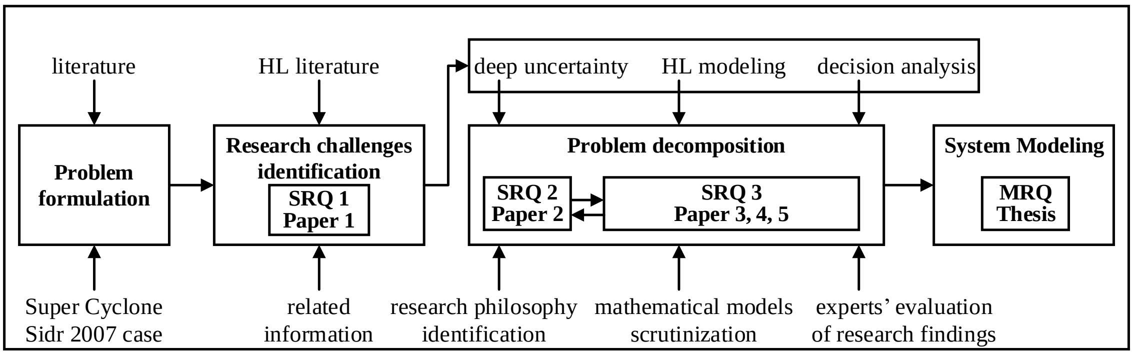


Figure 1.3: The storyline of this study

1.5 Empirical Setting

As depicted in Figure 1.3, the research problem for this study was motivated by the 2007 Sidr super cyclone. My own participation in this relief operation enriched my procedural understanding of disaster response—from procurement to distribution. Afterward, to validate the elicited (literature-based) system requirements, the 2015 Nepal earthquake and the 2018 Indonesia earthquake cases were also selected. This section explains the reasons for choosing these two cases.

First, the idea of this research emerged from my participation in the 2007 Sidr relief response in my home country, Bangladesh. While formulating this research problem, I used my understanding, observations, and thoughts gained from the Sidr case.

Second, since this study is rooted in the context of a developing country, I considered choosing countries with similar economic and societal infrastructures for further data collection and evaluation. So, I selected Nepal and Indonesia, studying their devastating earthquakes, which occurred in 2015 and 2018, respectively. Personal and institutional links in these countries also helped me getting experts onboard.

Third, the Indonesian earthquakes happened just before this study's data collection period. Therefore, it was an excellent opportunity to find active experts responding to the disaster. Although the incident in Nepal was a bit old by comparison, I chose to study it to obtain mature feedback on the enlisted decision factors.

Fourth, the earthquakes in both Nepal and Indonesia caused logistical challenges for the attending HDMs because of the areas' topographies (mountainous and island, respectively), fragile social infrastructures (remote regions that are easily disconnected), and economic instability in rural and remote areas (Dahal, 2016; Hayakawa and Tada, 2019, p.91; Thapa, 2012).

Finally, both countries experience political restlessness, corruption, ethnic disagreement, and poverty; they also have remote regions with limited accessibility (Paul et al., 2017; Thapa, 2012; Wahid, 2013). These factors, in many cases, largely affect relief operations in the field. Investigating these empirical settings supported my research in developing a practical understanding of how operational uncertainties were addressed and how HRD decisions were made.

However, although I initially focused on these regions for empirical study, my recruitment included experts worldwide (covering four continents: Asia, Europe, North America, and South America) with extensive experiences in DM and response. Twenty-three humanitarian experts finally participated in this study. They were affiliated with more than 20 national and/or international organizations, such as Logistics Cluster, Nepal Army, the World Food Program, the AHA Center, the National Disaster Mitigation Agency, NetHope, WeRotics, Dompet Dhuafa, Perkumpulan Lingkar, Mohammodia Disaster Management, Humanitarian Indonesia, and National Walhi.

In taking all participants onboard, a panel was formed to examine and validate the applicability of the decision factors identified from the literature for HRD and its operational ecosystem. Since participating experts were geographically distant from one another, the Delphi technique[15] was identified as a suitable data validating method (Rahman and Majchrzak, 2020). Each panelist was individually contacted (via e-mail) for data exchange, distributing the surveys for rating the identified decision factors, and collecting answers. Since none of the participants were exposed to the others, the raters were expected to be unbiased. The participants' responses were further analyzed to identify decision factors not covered in the literature but essential to practical decision-making, as well as to develop a prioritized list of accumulated decision factors and the correlations between them.

1.6 Synopsis of Contributions

This dissertation encompasses the entire story of my doctoral research. Here I link a historical case with two recent cases to support HDMs' HRD–DM under DU. A DSS model, incorporating findings from five research papers, is proposed to assist with such critical humanitarian response operations of humanitarian response. Four papers have already been published in academic outlets, whereas Paper 4 is under review by an international peer-reviewed humanitarian journal. The theoretical, empirical, and/or methodological insights provided by each paper support the research theme to answer the MRQ. The contributing research papers are listed in Table 1.1.

Table 1.1: Summary of publications

ID	References
Paper 1	Rahman, M. T., Comes, T., and Majchrzak, T. A. (2017). "Understanding decision support in large-scale disasters: challenges in humanitarian logistics distribution" in Dokas, M.I., Saoud, N.B., Dugdale, J., and Diaz, P. (eds.) *Proceedings of the international conference on information systems for crisis response and management in Mediterranean countries*. Xanthi, Cham, Switzerland: Springer, pp.106-121. DOI:10.1007/978-3-319-67633-3_9

[15] The Delphi technique is a process of collecting opinions from domain experts on specific topics through group communication and discussion (Llave, 2020).

ID	References
Paper 2	Rahman, M.T., Majchrzak, T.A., and Comes, T. (2019). "Deep uncertainty in humanitarian logistics operations: decision-making challenges in responding to large-scale natural disasters", *International Journal of Emergency Management*, *15*(3), pp.276-297. DOI: 10.1504/IJEM.2019.10023857
Paper 3	Rahman, M.T. (2018). "Pragmatism in decision support system research: the context of humanitarian relief distribution", *International Journal of Information Systems for Crisis Response and Management*, *10*(3), pp.63-83. DOI: 10.4018/IJISCRAM.2018070104
Paper 4	Rahman, M.T., Majchrzak, T.A., Comes, T., and Sein, M.K. (submitted 2020). *A conceptual framework to support decision-making in humanitarian relief operations*. Under review in an international peer-reviewed humanitarian journal
Paper 5	Rahman, M.T., and Majchrzak, T.A. (2020). "Requirements for relief distribution decision support in humanitarian logistics" in A. Siarheyeva et al. (eds.) *Advances in information systems development (ISD 2019): lecture notes in information systems and organisation*, *39*, pp.93-112. Cham Switzerland: Springer. DOI: 10.1007/978-3-030-49644-9_6

Table 1.2 presents a brief overview of this dissertation's generalized contributions by mapping the RQs, papers, and their main findings.

Table 1.2: Mapping of RQs, addressing papers, and main findings

RQs	Papers	Main findings
SRQ 1	1	The three major challenges in this research are found to be: DU in humanitarian operations, HL modeling, and decision analysis. The remaining SRQs address these challenges to answer the MRQ and model the envisioned humanitarian DSS for HRD–DM.
SRQ 2	2	A modified adaptive robust design (mARD) was proposed for addressing DU in HRD–DM.
SRQ 3	3	There is no significant philosophical understanding of HL research. The underpinning of the pragmatic paradigm was identified as appropriate for humanitarian DSS research. It supports mixed-methods for data collection and analysis.
	4	The selected studies mainly assisted in identifying problem areas in HL operations, their associated decision factors, and their interconnections. This finding further initiated a formulation of an operational ecosystem for HRD–DM.
	5	The identified decision factors from literature and practice were validated and prioritized. A correlation matrix was proposed between decision objectives and decision variables and constraints.
MRQ	Dissertation	Based on experts' opinions, the operational ecosystem was verified. It combined findings from Papers 2-5 to design the proposed humanitarian DSS model, which was intended to support decision-making for effective and efficient HRD.

1.7 Structure of this Dissertation

This dissertation is made up of eight chapters clustered into three development layers: research foundation, empirical analysis, and implications. The first layer encompasses the introduction to this research, its theoretical foundation, the background study on HL research, and the research design. The second layer presents data collection and analysis, research publications, and findings. Finally, the third layer articulates the contributions and conclusions of this research. Figure 1.4 presents the project's layered structure.

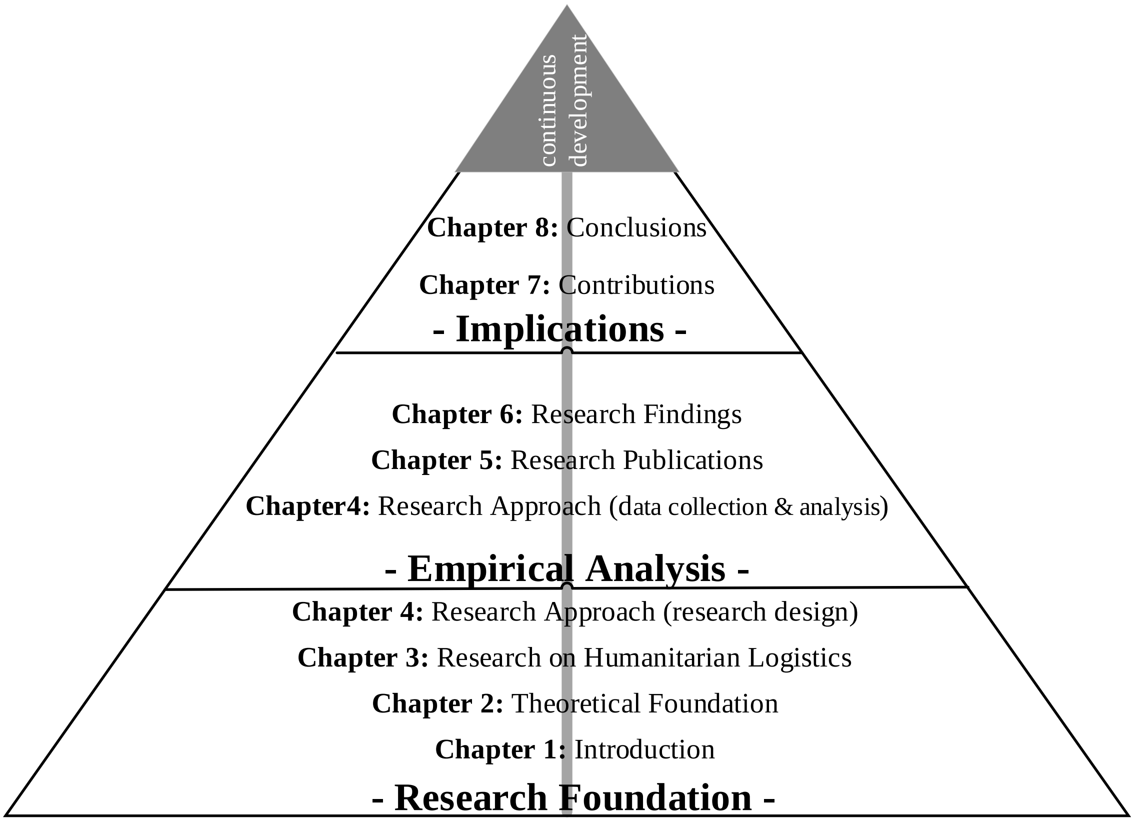
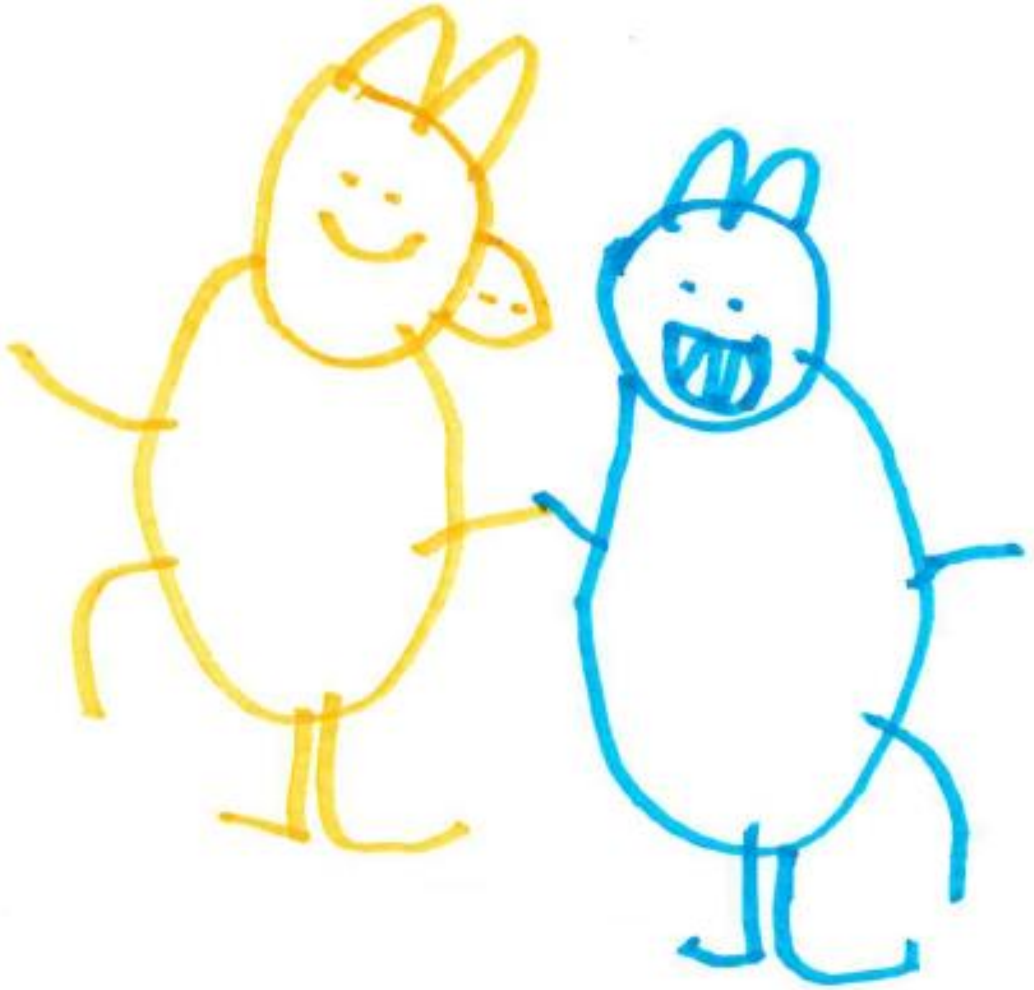


Figure 1.4: Structural pyramid of the dissertation

While introducing this research in Chapter 1, I presented the study's scope, background, motivation, RQs, empirical setting, key findings and contributions, and structure. The dissertation's multidisciplinary theoretical background is articulated in Chapter 2. Rooted in the IS discipline, I conceptualized three other theoretical perspectives in this study: HL, DSSs, and DU. Afterward, in Chapter 3, the study's rigorous and systematic literature review (SLR) is demonstrated to identify affecting problem areas, their associated decision factors, and their interconnections. Humanitarian experts validate the findings from this chapter through a ranking-type Delphi study. The entire research approach is presented in Chapter 4, which discusses the philosophical foundation of this project, along with the research methodology, data collection, and data analysis processes. Both the Delphi study and the data collection are also validated from IS perspectives in this chapter.

The results from the five publications and their relation to the entire study are presented in Chapter 5. Then, in Chapter 6, the formulated RQs are answered, accumulated, and connected to propose the envisioned humanitarian DSS model. All contributions (theoretical, methodological, and practice) of this dissertation are presented in Chapter 7. Finally, I draw the overall conclusion of this dissertation in Chapter 8 by highlighting the limitations of the study and suggesting future research avenues.



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2 Theoretical Foundation

2.1 Information Systems

To assist and improve managerial decision-making, DSS design and development are widely studied in the IS discipline (Arnott and Pervan, 2014). IS professionals contribute to building such IS artifacts (as computer software) by incorporating diverse functionalities and use in different business and organizational settings (Power, 2002, p. 56). To support strategic, tactical, or operational decision-making, DSSs establish interactions between ISs and decision modeling, thereby processing necessary data (Koutsoukis et al., 2000). Hence, Lee et al. (2015) divide the system building process into three interactive subsystems: technology (human-created tools for solving problems), information (instantiated through direct or indirect human acts), and social (interactions between humans). However, based on the encompassing properties, the ultimate product is greater than the sum of its parts.

To define effective HL responses in complex disaster environments, designing decision support technologies requires technical and organizational planning (Comfort et al., 2001). Since my study encompasses no such technical or organizational planning, I will not cover the technological artifact designing portion of the DSS creation process in this research. However, developing such technology for the proposed DSS would be an excellent future research direction, which this study could support by having conducted the requirement analysis for the system. To elicit the necessary system requirements and explain the design process of the envisioned DSS, the prescriptive theories from the scientific literature must be examined (Walls et al., 1992). Hence, to design the other two artifacts (informational and social), I require IS design theories recommending decision-makers with a manageable set of decision factors and, at the same time, system developers with a set of system requirements (Markus et al., 2002).

Practical HRD–DM is a multidisciplinary research area (Sohn, 2018). Researchers from these various disciplines—such as decision science, operation research, computer science, social science, business, engineering, supply chain management, IS, etc.—should contribute to improving decision-making support for effective disaster response (Baharmand et al., 2015; Schumann-Bölsche, 2018; Van de Walle and Turoff, 2008). However, according to Behl and Dutta (2019), such an integrating initiative is still missing in the existing HL literature. Due to diversities in the body of extant literature, as well as the attendant theories and founding philosophies, conducting multidisciplinary research is not straightforward (Meriläinen, 2018). Since researchers prefer studying alongside colleagues with whom they share similar interests or backgrounds (Behl and Dutta, 2019), multidisciplinary research in DSS for HL has, thus far, been insufficient.

However, while analyzing and modeling humanitarian operations, Widera et al. (2013) suggest examining previous HRD networks to achieve a holistic understanding of the process and identify the involved actors (i.e., decision-makers). Furthermore, for faster response, Jahre et al. (2009) recommend conceptualizing the centralization and decentralization of facilities and functionalities. Therefore, to define the systematic nature of the envisaged DSS, the following aspects must be conceptualized and linked: the decision environment, the function within this environment, the functional components that make it up, the links between these components and functions, and the resources required (Ariav and Ginzberg, 1985).

Hence, to identify empirically testable system design requirements, this study has necessitated examining theories outside the IS domain (Markus et al., 2002): HL, DSSs, and DU. These academic disciplines are briefly covered in the subsequent sections. However, it is important to clarify that decision analysis, decision-making, decision support, and decision modeling are conceptualized, in the dissertation, from the system development viewpoint of software engineering (SE) (Nunamaker Jr et al., 1990; Sprague Jr, 1980). Such understandings have assisted me in developing the information and social part of the desired IS artifact. Since developing supporting systems for decision-making is expected more often than creating additional algorithms (Watson, 2018), the insights and findings from this dissertation will help future researchers develop the artifact's technology portion. An interactive DSS system can, therefore, be built to generate information and support users with decision-making for specific tasks or problems (Sprague, 1980). The system can then undergo implementation and testing phases to confirm its workability. Figure 6.1 and Figure 8.1 demonstrate such a process for developing a humanitarian DSS for HRD–DM.

Figure 2.1 demonstrates the multimethodological approach to this humanitarian DSS research. It provides an overall understanding of the study's theoretical, experimental, observational, and developmental foundations. Since prototyping and developing the system is the ultimate aim of IS research, DSS development is at the center of the (developmental) process. Establishing such a system requires active and continuous support from theory building, conceptualizing IS artifacts (experimental), and encompassing influential research areas (observational). These four wings of IS development also offer feedback to each other for necessary updates. Concerning theory building, this research contributed by proposing a system model (covered in Chapter 6) by incorporating frameworks from the outcomes of the accompanying research articles (Papers 2–5) and conceptualizing problem areas, decision factors and their correlations, and the operational ecosystem of HRD. To support such theory building and system modeling, this study considered the information and social aspects of IS artifacts. Based on the formulated problem statement, this study identified DU, HL, and DSSs as the most impacting research areas to the supporting system for last-mile HRD–DM. Since the *technology* and *system development* aspects of the DSS are not covered in this study, they are shaded in Figure 2.1.

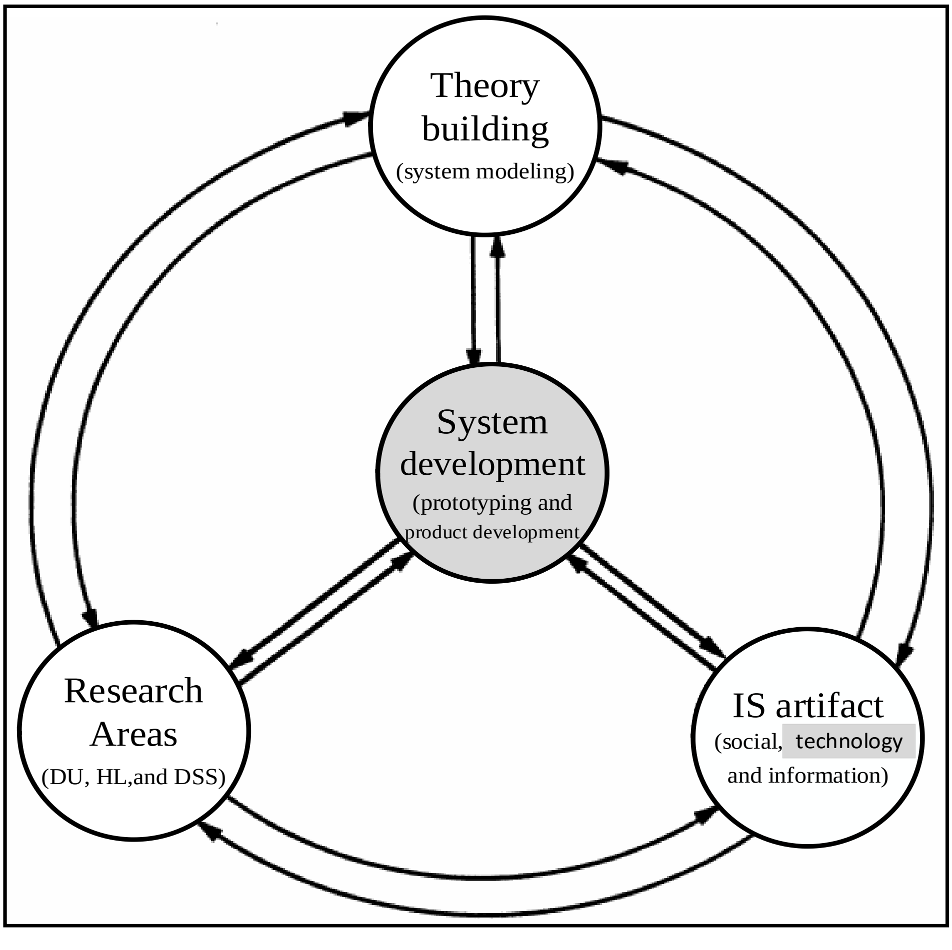

Figure 2.1: A multimethodological approach to humanitarian DSS research (adapted from Nunamaker Jr et al. [1990])

2.2 Humanitarian Logistics

According to the existing literature, decision-making in HL is mostly supported by sophisticated and context-specific mathematical models and simulations (Ortuño et al., 2013) with little concentration on practitioner realities (Widera and Hellingrath, 2016, p.340). When necessary, various decision factors are used in these models to optimize decisions, but they are never traced or studied further. However, such analyses are essential for understanding decision processes in humanitarian operations, as well as comprehending how these factors are used for decision-making in various problem areas that affect HRD decisions. For instance, while responding to disasters, practitioners face and solve decision-making problems in the areas of relief procurement, warehousing, transportation, and effective distribution (Maon et al., 2009). To distribute relief goods within a shorter time, HDMs require adequate support for addressing operational uncertainty, maintaining crucial communication and coordination, and exploiting limited resources to achieve efficient and timely delivery (Caunhye et al., 2012; Fritz Institute, 2005; Hellingrath and Widera, 2011).

To approach these challenges, İlhan (2011) recommends an adaptive and robust HSC, which can produce cost-efficient material flows, financial value flows, and adequate information flows to support operational decision-making in HL. All such practicalities of HRD are covered by the downstream part of the HSC: from entry points (initial staging of relief goods) to demand points (Baharmand et al., 2015). Baharmand et al. (2015) demonstrate how in-country HL operations could be performed—from managing port entries to HRD. Hence, I examine the downstream part of the HSC to identify decision factors associated with different problem areas that affect decision-making in HRD. Figure 2.2 illustrates a typical HSC of humanitarian operations in disaster responses.

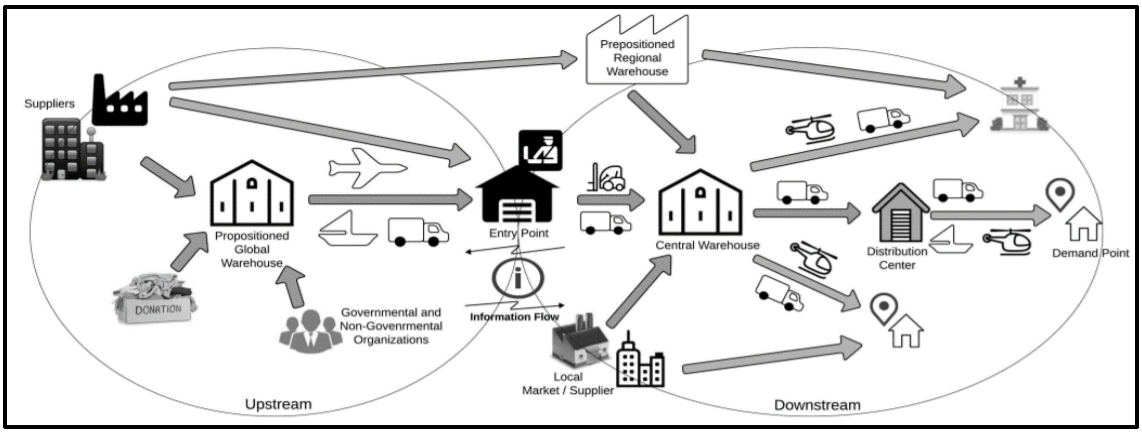

Figure 2.2: Operational overview of HSC (Baharmand et al., 2015)

Furthermore, a better philosophical understanding of HSCs is essential for identifying a suitable approach for requirements elicitation and the anticipated DSS design. For decision-making in HRD, the various decision or optimization models used in disaster response can be analyzed to determine problem areas and essential decision factors. Such findings can be characterized as requirements for the envisioned DSS, although ground truth can only be found through practitioners. Thus, the outcomes from the literature analysis can be validated by the domain experts—evaluating their applicability in practice. Such a DSS will provide adequate decision-making support to the HDMs, not only when delivering prioritized relief goods but also when communicating with decision-makers in different problem areas for effective distribution in the field. An interactive IS can support the development of a DSS by integrating resource databases, community collaboration, collective memory, and online communities of experts (Turoff et al., 2004). The following section, therefore, discusses how such a DSS can be designed.

2.3 Decision Support Systems

Sprague (1980) understands DSS as an IS that is able to support and improve the performance of its users in specific contexts through applying information technology. This conceptualization of DSS supports the already discussed sub-systemization of IS artifact development proposed by Lee et al. (2015): technology artifact, information artifact, and social artifact. Such a system is highly interactive and allows users to access data, build and use various models, and explore alternate scenarios (Watson, 2018). However, operational responses are always hampered by the diversity of information and its distributed ownerships, which cause information inaccessibility, a lack of information, and/or information overload (Zhang et al., 2002). Therefore, a flexible and dynamic computerized operational system can support decision-making and help its users to accomplish the complicated tasks of complex humanitarian problems (Comes and Van De Walle, 2016). Such a DSS should be able to handle large datasets, process complex queries, and generate faster results in the desired formats (textual, tabular, and/or graphical). In this regard, Van de Walle and Turoff (2008) urge developing an interactive IS to support system development along with a set of generic design principles. Watson (2018) articulates the following salient characteristics for a DSS, which frequently appear in the literature.

- **Data format:** focus on managers' and executives' semi-structured and unstructured decision-making tasks.
- **Types of decisions:** support for independent and interdependent decision-making (e.g., group) and all phases of the decision-making process (i.e., intelligence, design, and choice).
- **Use of models:** integrated models with traditional data access and retrieval techniques.
- **System features:** focus on features that make the system fast and easy to use interactively by non-computer specialists.
- **Coping with changes:** emphasizes flexibility and adaptability to changes in the environment and users' decision-making approaches.
- **System development:** recommends evolutionary and iterative development methodology for system building.

To support this study and system design, I determined that the *decision information system* (DIS) model proposed by Wallace and De Balogh (1985) (Figure 1.2) and the *DSS reference architecture* (DRA) model proposed by Watson (2018) (Figure 2.3) are suitable for further discussion.

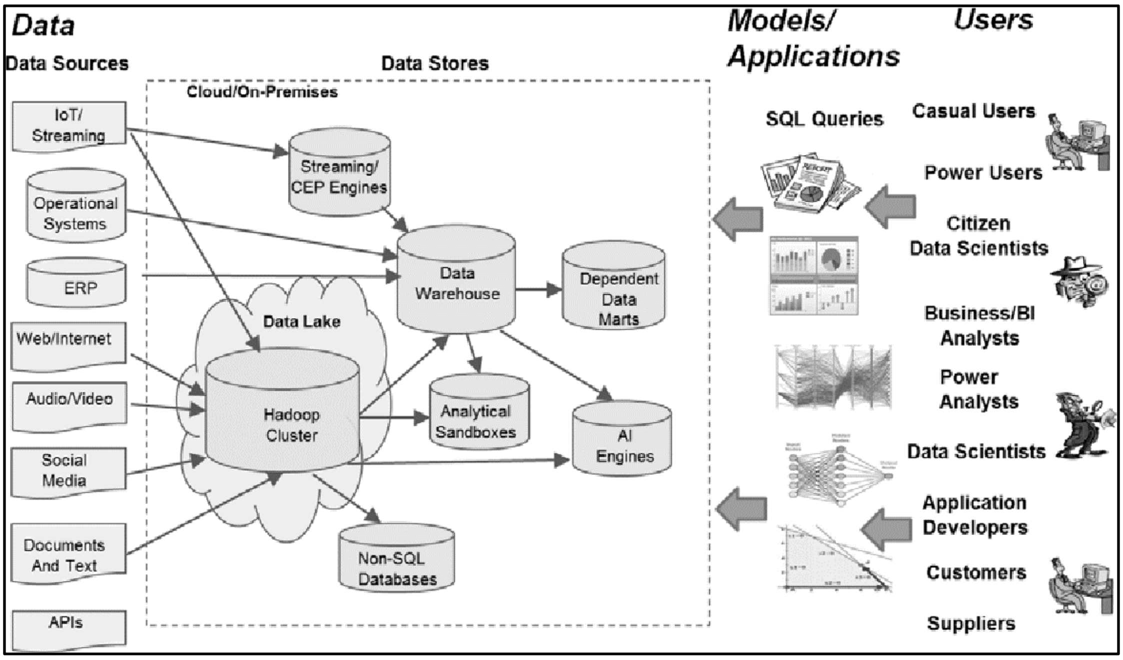

Figure 2.3: DSS reference architecture (Watson, 2018)

When compared, both designs show similar core mechanisms, components (users, data stores, models, and technology), and management systems (data, model, and dialog). Due to significant technological enhancement, the notion of the *databank* in the DIS model can be replaced by modern data stores with more substantial space, such as *cloud/on-premises* repositories (as recommended in the DRA model). However, since the DIS model is specially designed for disaster response, I found it more suitable than the DRA approach for this study. The DIS approach conveniently demonstrates its components, typical data flows, and direct connectivity to the responding environment and decision-makers. Its interactive features and management systems are introduced below, along with some adaptations taken from the DRA approach.

System Components:

- **Datastores:** cloud-based or on-premises solutions for storing data about the disaster environment, available resources, current weather, and necessary decision-making information (Watson, 2018).
- **Data analysis capability:** a quantitative process of necessary data for appropriate decisions.
- **Normative models:** provide solutions that are not readily apparent, evaluate the trade-offs between alternative solutions, and recommend possible actions to be taken.
- **Easy-to-use user interface:** provide a fast and easy way to connect system components and access, specially prepared data, which can be displayed and further analyzed by decision-makers (Watson, 2018).

Management Systems:

- **Model base:** generates proper data queries and submits them to data stores.
- **Database:** accepts users' queries and provides the required data in the desired format.
- **Dialog:** controls the interface between users and system functions.

The DIS framework, along with adaptation from the DRA model, was further enhanced in this dissertation to design the desired DSS for HRD–DM. The resulting system incorporates concepts developed in affiliated research papers (Papers 2–5). However, to operate effectively in unpredictable and dynamic disasters, DSS must tackle different operational uncertainties (Altay and Green, 2006; Ansell et al., 2010). The following section discusses how DU can be addressed in humanitarian operations.

2.4 Deep Uncertainty

Since this topic is fully covered in Paper 2, here I present a succinct summary of the discussion to reduce repetition.

In disasters, 80% of responding operations encompass distributing humanitarian relief (Tomasini and Van Wassenhove, 2009). Supply and demand in humanitarian relief operations are precarious (Widera et al., 2013). When the required information is unavailable or inaccessible in a dynamic disaster environment, such uncertainties can be conceptualized as *severe or deep* (Comes et al., 2015b), a crucial barrier to operational decision-making (Anderson et al., 2014). Again, many hard-to-measure decision factors and their interdependencies, multiple methodologies, and model alternatives can make decision-making cumbersome (Doyle et al., 2019; Jiang and Yuan, 2019; Sword-Daniels et al., 2018). Decision-makers in such situations become puzzled about decision objectives, constraints, model parameters, and alternate outcomes (Ansell et al., 2010; Baharmand et al., 2015). Due to their diverse understandings and aims, many actors and stakeholders also create instability in decision-making. Such challenges cannot be addressed by human beings alone. Technical procedures and mechanisms are necessary for obtaining crucial, relevant information to approach these complexities rapidly and systematically.

To deal with DU, Walker et al. (2013) indicate that developing knowledge about past, current, and future disastrous events is imperative. Doyle et al. (2019) also emphasize extensive study to identify suitable methods for finding, classifying, and addressing operational uncertainties. As this topic is sparsely discussed in HL literature, approaches to DU, developed in other fields, may be examined and applied to HRD–DM. To facilitate work, Marchau et al. (2019) and Rahman et al. (2019) evaluate the available approaches to DU and group them as follows.

- **Robust decision-making** uses computation, not for better predictions, but to reach better decisions.
- **Dynamic adaptive planning** includes provisions for adaptation as conditions change and knowledge is gained.
- **Dynamic adaptive policy pathways** include decision-making over time, considering how the future unfolds.

- **Info-gap decision theory** prioritizes alternatives and making choices and decisions, focusing on what is known and what must be known for decision-making.
- **Engineering options analysis** handles multiple decision-making options simultaneously and allows for all sorts of measures of benefits and values.

As recommended by İlhan (2011), adaptive and robust approaches should be examined to identify their applicability to HL, specifically to HRD–DM. Since available DU tackling methods focus on longitudinal environmental/climatic problems, they cannot directly be applied to HL problems (Rahman et al., 2019) since they require practical solutions for rapid disaster response to alleviate survivors' suffering (Rottkemper and Fischer, 2013). Additionally, the solutions, by design, must simultaneously be adaptive to cope with the frequently changing disaster environment and robust to perform well in all conditions (Cordeiro et al., 2014). Hence, both adaptive and robust decision-making approaches, with necessary modifications, can be applied to HL issues (Rahman et al., 2019). Paper 2 presents a detailed study on DU tackling mechanisms to help readers better understand the variations in application contexts and their techniques. The paper also discusses the applicability of those approaches in HL operations, especially in HRD.

2.5 Chapter Summary

For effective decision-making in HL activities, a multidisciplinary team effort is necessary (Van Wassenhove and Pedraza Martinez, 2012), and systems development should follow multidisciplinary approaches (Taniguchi et al., 2012). Theoretical models from different research disciplines must be studied to assess their decision-making capabilities in the HL context (Taniguchi et al., 2012). Hence, this dissertation has carefully consulted the above theoretical dimensions to address the RQs (reported in Chapter 1) and derives innovative solutions for supporting HRD–DM. By presenting the theoretical background, this research participates in developing novel principles for design theories concerning humanitarian DSSs and, thus, according to Markus et al. (2002), contributes to the IS field. The research can be extended to designing IS artifacts (i.e., an interactive DSS) by using information from appropriate sources and technology with an exact working procedure (Gregor and Jones, 2007; Walls et al., 2004).

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3 Research on Humanitarian Logistics

Decision-making in HRD is not a standalone problem; its effective operation incorporates other issues as well (Gupta et al., 2016). All these problem areas have their own sets of decision factors for operational decision-making (Rahman et al., Under review). In the current research trend, problem areas are individually examined to propose problem-area-specific decision models for achieving different decision objectives (Roy et al., 2012). However, for effective last-mile HRD, Roy et al. (2012) argue for concurrent decision-making between problem areas. Hence, problem areas (for HRD–DM) must be identified along with their decision-making characteristics and interdependencies (Pettit and Beresford, 2009). To accomplish this, I rigorously and systematically reviewed extant and relevant HL literature. This review not only provided a sound basis for understanding HL as a discipline but also enhanced my knowledge of its critical and complex tasks. To present this process of examining topic-specific information sources and materials, this chapter continues by initially detailing the literature review and analyses and then summarizing and discussing the findings.

3.1 Systematic Literature Review

To conduct this rigorous SLR, I adapted the guidelines proposed by Vom Brocke et al. (2009) for IS research as an umbrella framework. Their framework comprises five consecutive steps: (1) definition of review scope, (2) topic conceptualization, (3) literature search and evaluation, (4) literature analysis and synthesis, and (5) research agenda. However, to gain better review results for this IS research in HL, I incorporated concepts from other approaches into Steps 2–4. For example, by following recommendations from Denyer and Tranfield (2009), this review's questions were clearly defined in Step 2. Such an understanding helped me to establish the focus of the review, its search strategy, and data extraction procedures. Since HL covers a broad range of literature (L'Hermitte et al., 2015), I restricted the search results in Step 3 by adapting guidelines from Anaya-Arenas et al. (2014). Lastly, the content analysis process model from Seuring et al. (2005) was employed in Step 4 to conduct an extended analysis of the literature via descriptive analysis, category selection, and material evaluation. I also modified a previously established categorization technique for HL literature (Leiras et al., 2014) to identify concealed categories. The entire review process is demonstrated in Figure 3.1 and described afterward.

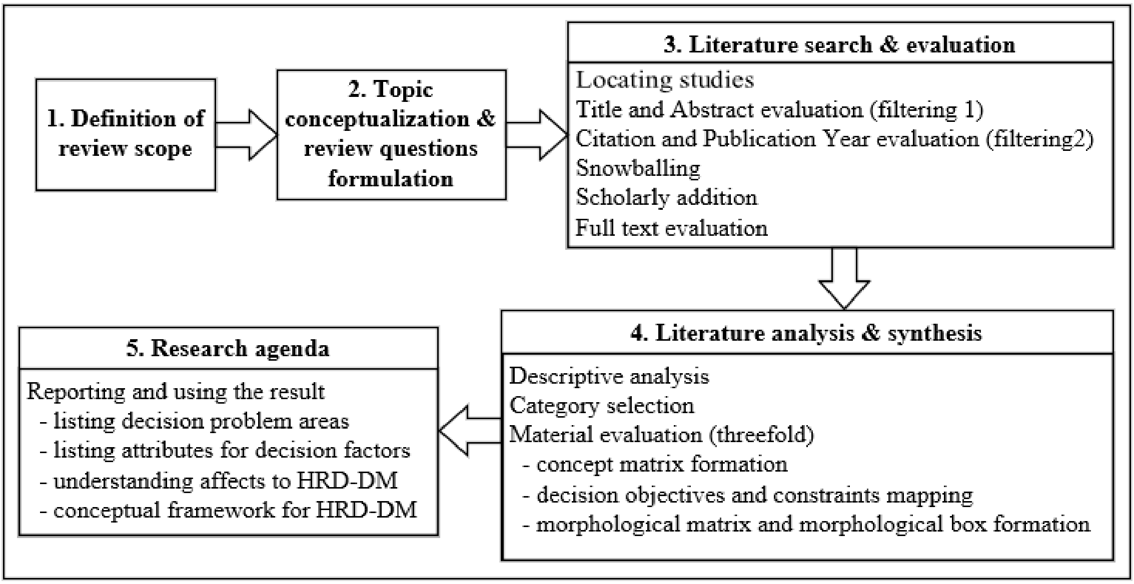

Figure 3.1: The framework for this SLR

3.1.1 Definition of the Review Scope

As literature reviews develop topical bases for research, defining an appropriate review scope is a significant challenge for researchers (Vom Brocke et al., 2009). To identify a proper review scope, I incorporated Cooper's (1988) taxonomy in the review process. This exhaustive and systemized taxonomy involves categorizing six characteristics for each piece of literature (Table 3.1): (i) study's emphasizing points, (ii) intended findings, (iii) organizing structure, (iv) espousing positions, (v) targeted readers, and (vi) degree of coverage of sources.

Table 3.1: Categorizations in this literature review (adapted from Cooper [1988])

#	Characteristics	Description
1	Focus	This SLR focused on the research outcomes from the literature, as well as the methods and theories used to produce those outcomes.
2	Goal	The goals were to: • Integrate past literature related to HL decision-making. • Identify problem areas and their decision factors. • Understand how HRD–DM is influenced by decision-making in those problem areas.
3	Organization	All references were clustered according to their similarity in conceptual development and were further sub-clustered based on the methods they employed.
4	Perspective	Since the research perspective was to accumulate literature regardless of subject area or outlet, this SLR supported a neutral representation of the content.
5	Audience	As part of my doctoral degree, this review targeted general scholars, especially in the HL field. However, researchers in other theorized disciplines (IS, DSS, and DU) and humanitarian practitioners can also receive valuable insights from its outcomes.

#	Characteristics	Description
6	Coverage	Although all relevant sources were considered, only a selective corpus was finally analyzed.

3.1.2 Topic Conceptualization and Review Questions Formulation

After defining the review scope, Vom Brocke et al. (2009) suggest conceptualizing the topic and summarizing the working definition of related key terms. I, therefore, began conceptualizing DSSs by defining their application areas. DSSs are researched and widely used in various subject areas. However, through the desired DSS model, this research aims to support practitioners' decision-making in distributing humanitarian relief in large-scale natural disasters (e.g., flood, earthquake, landslide, epidemic) rather than responding to daily emergencies (e.g., medical emergencies, policing, firefighting). According to Altay and Green (2006), disaster responses require knowledge of operation management techniques for situational analysis, optimization, probability, and statistics. Lack of such understanding makes it difficult for decision-makers to respond to disasters. To assist them with operational perceptions and decision-making support, I began modeling a DSS in Paper 1. Thus, Paper 1 conveys the necessity of identifying problem areas in HRD, their decision factors, and interconnections. Such tasks lead to studying HL (its supply chain modeling), decision analysis (for operational response), and approaches to DU. The following review questions guided this rigorous literature review:

- What are the interconnected problem areas in HRD?
- What are the decision factors for each of the problem areas, including HRD?
- How do those problem areas influence HRD–DM?

Figure 3.2 demonstrates the conceptualization of DSS in HRD–DM. To support operational decisions, the DSS should provide 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). Such a study must address the identified research challenges (HSC modeling, decision analysis, and DU).

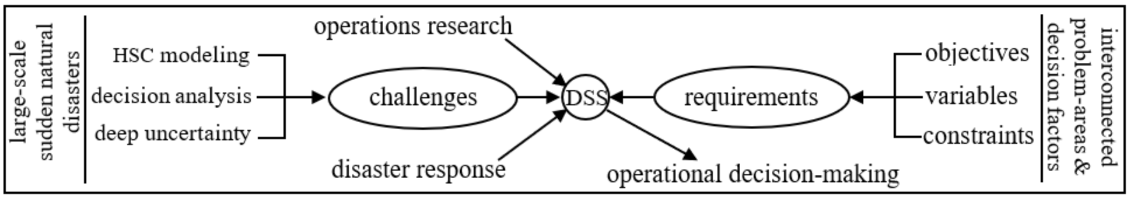

Figure 3.2: Conceptualization of the humanitarian DSS

3.1.3 Literature Search

The review plan was determined with a clear objective, article extraction strategies, inclusion and exclusion criteria, and an article examination and categorization mechanism. Individual references were examined to determine whether they should be kept in the literature stock, and, thus, a complete search was achieved. A quality review process was, therefore, completed—identifying and evaluating extensive literature in a systematic, transparent, and reproducible manner.

This section elaborates on the three steps of the literature search and selection process. “Step 1: Study identification” describes the keywords selection and how the literature was located in the academic databases. “Step 2: Study selection and evaluation” discusses the development of reviewing the literature corpus. “Step 3: Study addition” delineates the incorporation of the unidentified but essential literature through the snowballing technique. The overall literature search and selection procedure is illustrated in Figure 3.3, and the defined steps are subsequently elaborated.

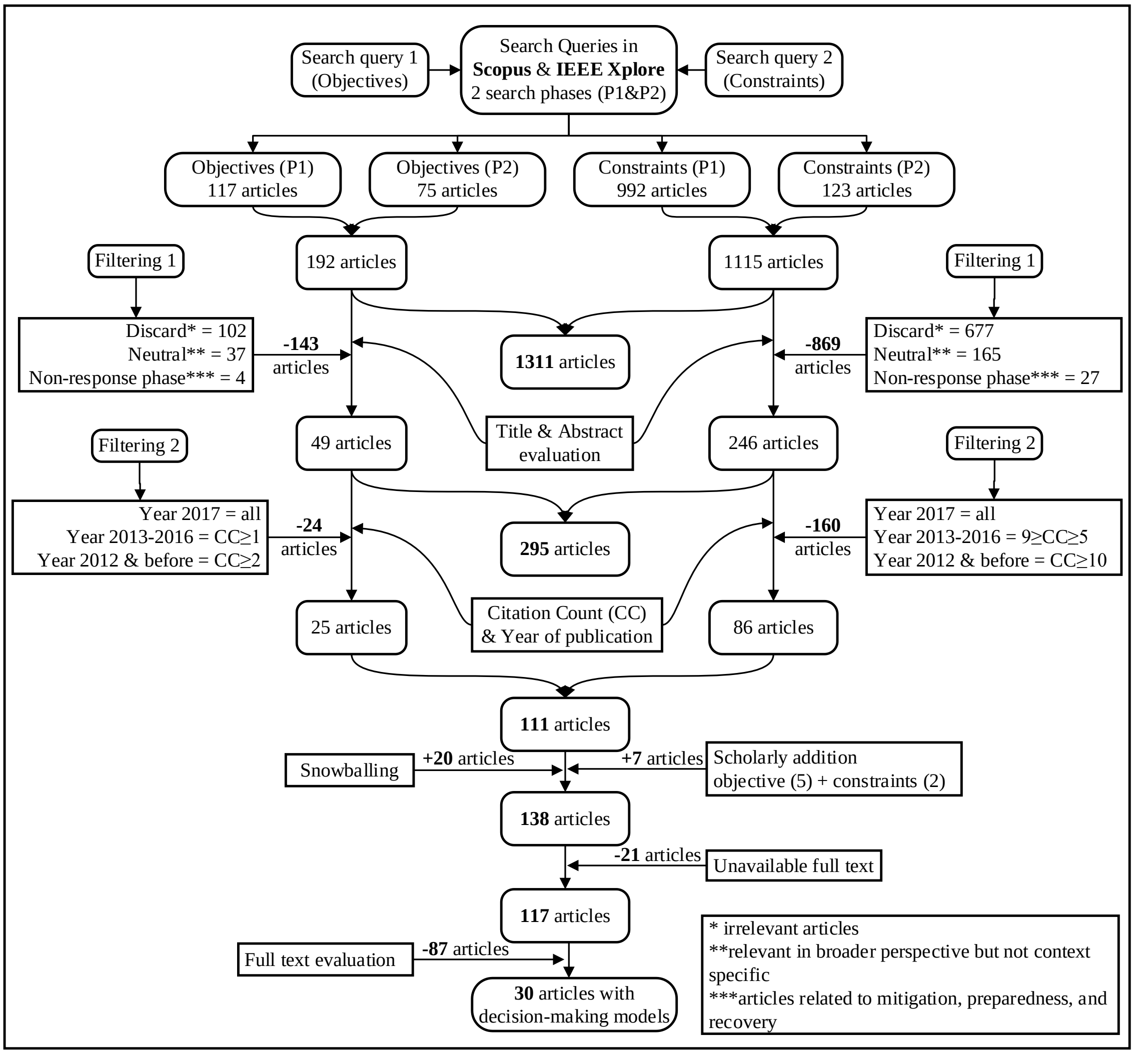

Figure 3.3: Literature selection procedure

Step 1: Study Identification. This section describes the selection of essential keywords, the formation of search chains, and how the sampled studies were located in a process intended to collect adequate and pertinent literature.

Keywords Selection. To develop an operational DSS, eliciting necessary system requirements is vital. In this study, identifying problem areas and associated decision factors were the requirements for modeling the intended humanitarian DSS. The decision factors were defined as three elements: decision objectives, decision variables, and decision constraints. I intended to determine how the achievement of each decision objective is affected by various decision variables and constraints. Hence, I examined the HL literature for objective models or decision support models tuned to operate the HSC during disastrous events. These models were expected to provide me with a list of decision factors exploited in the relevant academic research. Thus, I set up the first search chain with a combination of keywords:

[(objective function or model or decision support) and (humanitarian or disaster) and (supply chain)]. To set up the second search chain, I concentrated on identifying decision factors that restrict rapid decision-making under DU in HL. Thus, the keywords were chosen accordingly: *[disaster and {(short time (rapid)) or ((deep) uncertainty or complexity)} and {decision making or decision support or humanitarian logistics}]*. The decision factors identified from the articles selected by both search chains were validated in the field and further formulated as system requirements. For explanation purposes, the search chains have been named *Objectives* and *Constraints*, respectively.

In both search chains, different iterations were applied with synonymous terms, except for the *disaster* keyword. This keyword is synonymously used for other terms in the literature, such as *crisis* or *emergency* (Al-Dahash et al., 2016). However, though these terms are often used interchangeably and sometimes in combination in the mainstream literature, there is a line of distinction between them. Al-Dahash et al. (2016) argue that “disaster” is the ultimate destination of “crisis” and “emergency” if the events they encompass are not addressed correctly or managed early. I found this argument sufficient and, therefore, used no synonyms for “disaster” in the search chains since this research focuses on sudden, natural-onset occurrences, which are mostly uncertain (about what has happened, when, where, to whom, etc.) and demand immediate responses.

Locating Studies. The above keyword combinations were entered into two multidisciplinary databases: Scopus and IEEE Xplore. Scopus is the largest repository for quality outcomes from multiple disciplines. It is easy to use and, thus, has a possible effect on research findings (Aghaei Chadegani et al., 2013; Boyle and Sherman, 2006). On the other hand, IEEE Xplore contains the highest number of quality pieces of technical literature concerning engineering and technology (IEEE Xplore, 2020). Only peer-reviewed articles in academic journals and conference proceedings were considered, with no restriction placed on research disciplines or publishing dates. The search process had two phases. The first phase contained entries published up to July 2016 (without restricting publishing year). The second phase incorporated articles published between July 2016 and August 2017. The entire process accumulated 192 papers for the *Objectives* category and 1,115 papers for the *Constraints* category. Altogether, 1,307 articles were taken to the next step for evaluation.

Step 2: Study Selection and Evaluation. Study selection and evaluation were conducted through three consecutive phases: Filtering 1, Filtering 2 and Snowballing. To identify potential literature, different measures were imposed during the screening process, such as defining the inclusion and exclusion criteria, evaluating citation counts and publishing years, and scholarly addition[16]. The phases are elaborated below.

Filtering 1. For maximum relevance, the titles and abstracts of 1,307 collected articles were examined in this phase. The relevant articles were clustered into four DM phases: mitigation, preparedness, response, and recovery. To address the review questions, the content of the *response* cluster was considered for further evaluation. I used the Mendeley reference manager to trace, track, and annotate each article. The annotation concisely described individual articles, along with a detailed inspection of the reasons for accepting or rejecting them. Such activities were performed based on the set of inclusion and exclusion criteria (aligned with the research aims) presented in Table 3.2. After this rigorous initial filtering, 295 articles were selected for further evaluation in the next stage.

Table 3.2: Inclusion and exclusion criteria for Filtering 1

#	Inclusion Criteria	Exclusion Criteria
1	Peer-reviewed papers in English: academic journals and conference proceedings; no temporal filtering	All other articles, such as non-English publications, duplicates, news, reports, etc.
2	Articles on large-scale, sudden-onset, natural disasters	Articles on other types of disasters
3	Several types of decision-makers (levels): operations/field-based and strategic	Articles with a generic focus or a sub-focus on HL
4	All DSS articles (mostly related to HL)	Articles on location and network planning
5	Humanitarian information management	Articles not proposing any information flow in HL
6	HL articles concerning data collection and response phases, not necessarily directly related to decision-making but provide discussions of data repositories necessary for decision-making.	Articles on disaster mitigation, preparedness, and recovery
7	Articles that discuss the preconditions for decision-making in the response phase	Articles on disasters but not discussing DSS, HL, or the HRD process
8	Articles that discuss the contexts and constraints for decision-making, including operational and strategic	Articles that focus on evaluation or field study
9	Articles that discuss the decision and coordination process	N/A

[16] Literature suggested by academic scholars in HL domain.

#	Inclusion Criteria	Exclusion Criteria
10	Articles that suggest HRD modeling	
11	Articles on transportation, scheduling, and last-mile problems	

Filtering 2. Since the number of articles for evaluation was still significant, the second round of screening was conducted. Identifying the trends of the publishing year associated with citation count is one way of further scrutinization. To do this, I examined the *citation counts (CC)* and *publication years* of the articles filtered in the previous phase. All contributions from 2017 were considered since they contained the most advanced information on the research topic and, hence, have lower citation counts. Articles published before 2017 were clustered differently for both categories. The accepting threshold for the *Objectives category* was CC≥1 for articles published between 2013 and 2016 and CC ≥2 for the rest. In the *Constraints category*, the accepting threshold was set to 9≥ CC ≥5 for articles published between 2013 and 2016 and CC ≥10 for the rest. After Filtering 2, the total number of sampled papers was reduced to 111.

Step 3: Study Addition. According to Webster and Watson (2002), a systematic search should produce a relatively complete literature corpus. To keep the repository updated with important and influential contributions, I applied a reference snowballing technique for backward search only. While reading each article, the references mentioned by authors as important and relevant were tracked. Using the authors' remarks on a specific reference, a concise overview was gained to identify the article's relevance to this study. However, to keep the corpus under control, the references of those references were not considered. In addition, three HL domain experts (from academia) were requested to scrutinize the resulting corpus and suggest missing but relevant literature. This process brought 27 more papers into the corpus. Thus, a total of 138 articles were selected for full-text evaluation.

Final Selection. After 21 inaccessible articles[17] from the 138 nominated ones, 117 papers remained for full-text evaluation.

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

3.1.4 Literature Analysis and Synthesis

At this stage, the collected literature was analyzed and synthesized to answer the review questions. I employed a descriptive analysis to obtain meta-information about the corpus and identify related categories for threefold material evaluation.

Descriptive Analysis. I exploited the bibliometric analysis technique to descriptively analyze the corpus. First, reviewing the yearly distribution of accumulated papers indicated that researchers have been interested in identifying and dealing with decision constraints since the early 1990s, while the first paper concerning decision objectives was published in 2006. In 2016, extensive works were published in both categories. Second, the study of subject area distribution proved that the concept of decision support is practiced in multiple disciplines, especially in computer science, engineering, decision science, the social sciences, business, management and accounting, environmental science, mathematics, and medicine. Third, the number of journals and conferences that accept disaster and HL papers is remarkable and, thus, indicates a profound interest in the field. However, this contributive engagement also evidences the complexity of HL problems, which require multidisciplinary work for optimal response. The analysis of country-wise distribution pointed out the emerging trend of cross-border research and reflected disaster outbreaks' disregard for international borders. Researchers from the United States and China dominate in both cross- and single-country studies. Finally, the subject-area interconnectedness analysis indicated that decision-making problems are not standalone. Researchers require knowledge from multiple disciplines, or colleagues from various disciplines should work together to obtain practical solutions.

Category Selection. As mentioned previously, I adapted the paper classification framework from Leiras et al. (2014) to obtain vital information on individual articles and a more comprehensive view. This framework comprises ten categories, which can jointly summarize individual papers if they are fed with appropriate data. Since this research focused on identifying the influential relationship between decision objectives and constraints, I added these points as two new blocks into the framework, portraying the complete picture. Although determining the associated decision variables was part of this dissertation's goal, these variables were handled outside of the framework since objective functions or optimization models are formulated by combining and controlling different affecting variables. Figure 3.4 demonstrates the article categorization framework for this study.

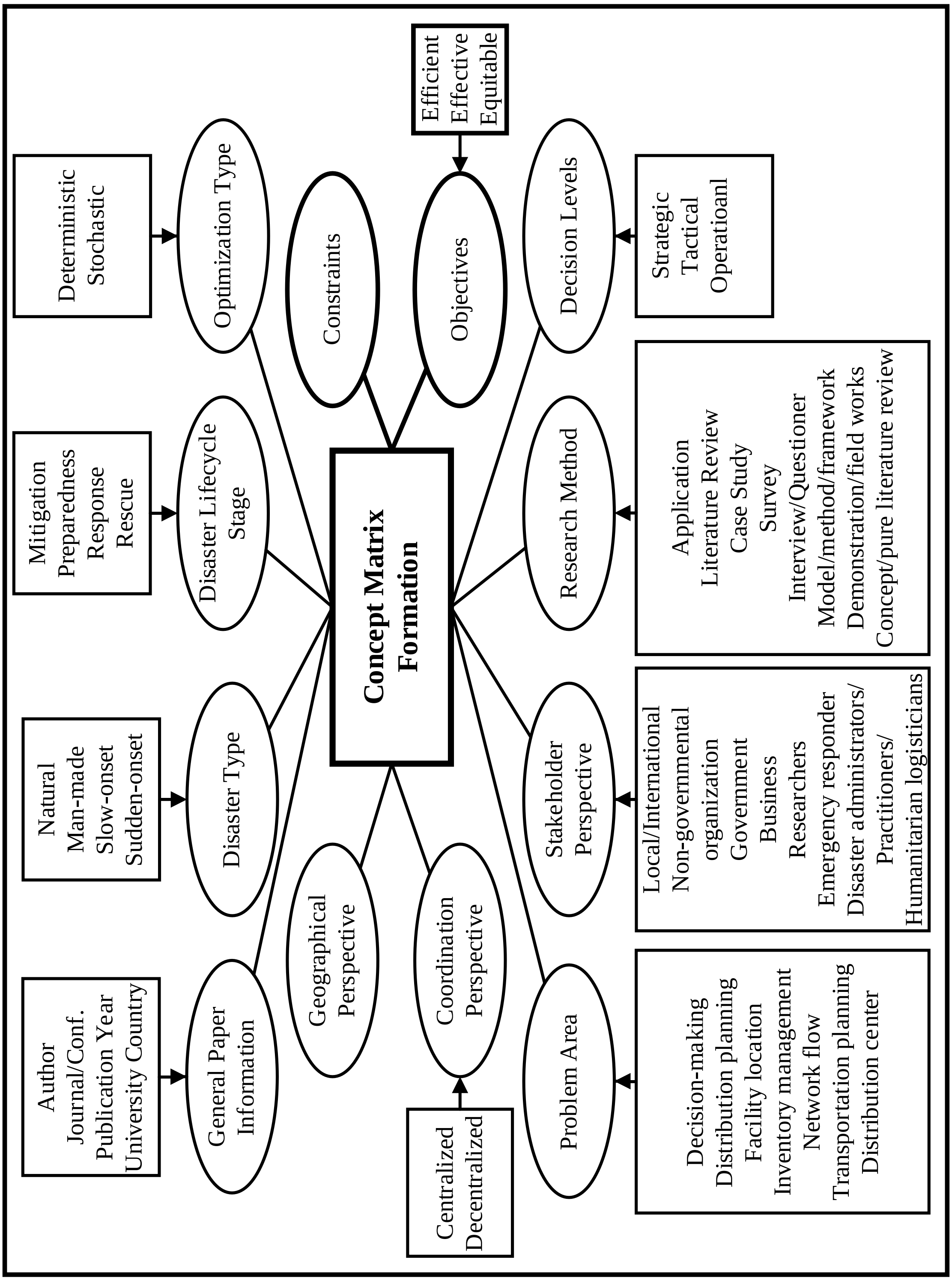

Figure 3.4: The categorization framework (adapted from Leiras et al. [2014])

Material Evaluation. A threefold analysis approach was employed to evaluate the 117 nominated papers. To arrange, discuss, and synthesize prior research in the first phase, individual papers were scrutinized based on the concept matrix prescribed by Webster and Watson (2002). To capture and place the necessary information in the concept matrix, each paper was carefully read, evaluated, and classified. While most of the papers deal with developing optimization models for decision-making in disaster response, some authors generalize their contributions as part of emergency management, which is not the same as DM. In these sources, specifications about the targeted disaster types were absent. Disaster response contributions from other research areas were also encountered and articulated in the concept matrix. Appendix A presents a sample of the formulated concept matrix for this research.

In the second phase, the formulated concept matrix was further inspected to identify articles that (i) focus on humanitarian operations during natural disasters, (ii) propose models, and (iii) encompass precise objectives and constraints. After scrutinizing all articles in both categories, 30 papers were shortlisted for in-depth evaluation to identify and map problem areas and their associated decision factors (objectives, variables, and constraints).

In the third phase, a morphological matrix was formulated to present the concept-centric analysis of the mapping. It encapsulated 13 problem areas, nine decision objectives, 26 decision variables, and 21 associated constraints. However, the morphological matrix demonstrated the tendency of multiple problem areas to have similar decision objectives, variables, and constraints. Appendix B presents the morphological matrix.

The morphological matrix was further analyzed by clustering conceptually similar decision objectives, variables, and constraints. This analysis is presented as a morphological box (Appendix C), where the number of problem areas is reduced to six by merging those that are, not only conceptually similar, but also have identical decision factors. Finally, a manageable, abstract view of the analysis was developed to visualize the connectivity of the problem areas and their influences on HRD–DM. Figure 3.5 graphically represents all decision factors encompassed by each problem area. Based on shared (or common) decision factors, the figure visualizes their connectivity, which was efficiently simplified to an operational ecosystem presented in Paper 4.

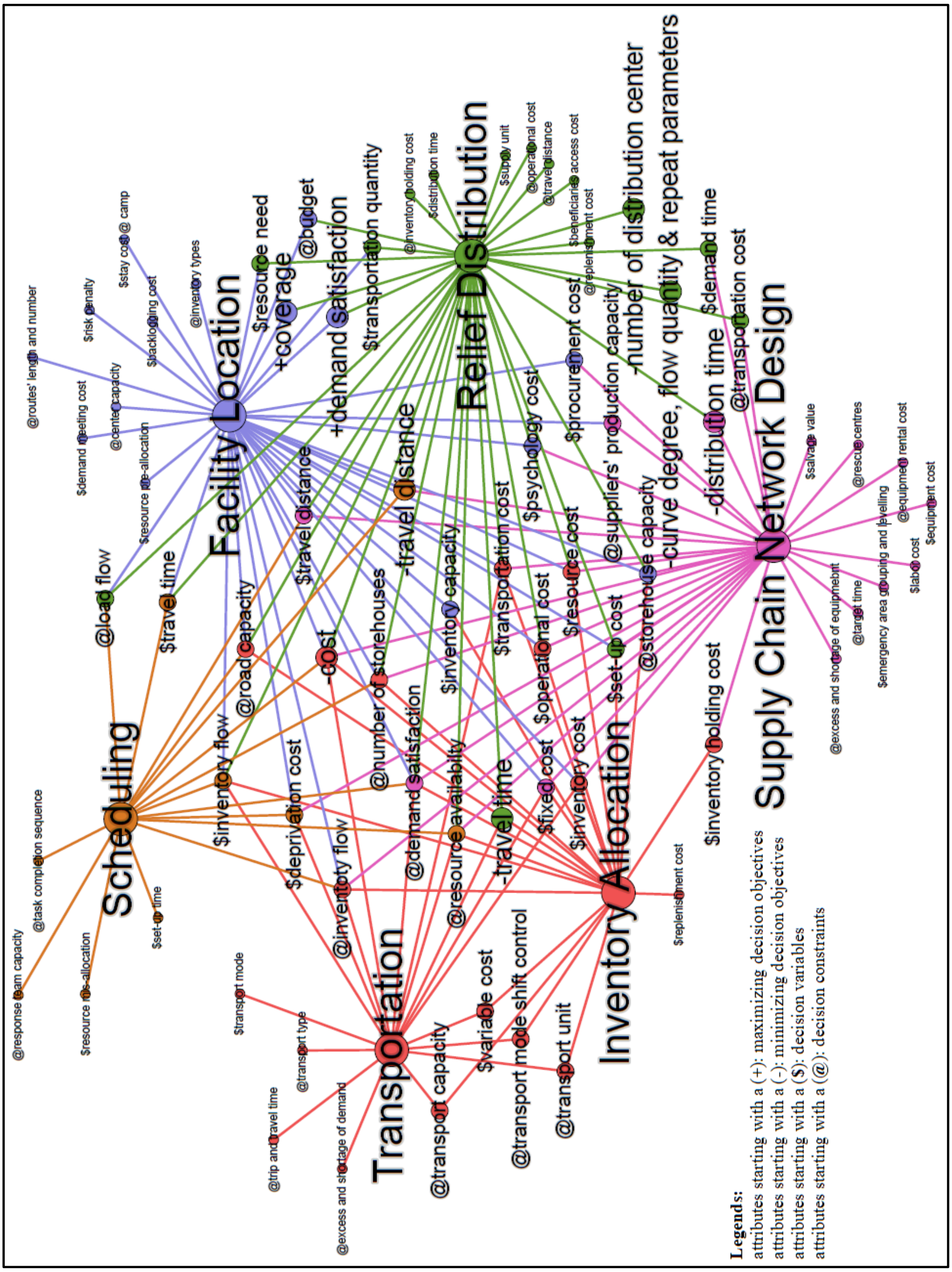

Figure 3.5: The detailed view of the connectivity between problem areas

3.1.5 Research Agenda

According to Vom Bocke et al. (2009), a research agenda provides guidelines for future research in the area of concentration, with sharper and more insightful RQs. In this case, when the concept matrix was completed, it became easy to identify the problem areas and their associated decision factors, based on which the interconnectedness between problem areas could be determined. The ecosystem was discussed along with its theoretical and practical contributions to building the DSS model for HRD.

3.2 Results of Focused Review

This study identified six problem areas in HL: humanitarian relief distribution (HRD), facility locations (FL), relief supply chain (RSC), inventory management (IM), transportation (Transp), and scheduling (Sched). The analysis continued evaluating the shortlisted decision models to identify and list decision objectives, along with variables used and constraints addressed. To generate a holistic understanding of decision-making in HL, shared (from other problem areas), frequent (exploited in multiple problem areas), and non-frequent (problem-area-specific) decision factors were tracked and mapped, as suggested in HRD. Although the problem areas and their associated decision factors are conveniently presented in Paper 4, they are also attached in Appendix D. This section continues by briefly explaining the identified problem areas, which are listed and conceptualized in Table 3.3 along with related articles.

Table 3.3: Identified problem areas, their conceptualization and related studies

#	Problem Areas	Conceptualization	Articles
1	**HRD**	Determines the effective distribution of relief items according to demand in a time-critical setting.	Barahona et al., 2013; Chunguang et al., 2010; Gralla et al., 2014; Liberatore et al., 2014; Rancourt et al., 2015; Ransikarbum and Mason, 2016; Rottkemper and Fischer, 2013; Tofighi et al., 2016.
2	**FL**	Determines the number of relief bases needed and their optimal, easily accessible locations.	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	**RSC**	Stresses the importance of quick product accumulation and processing for immediate response by optimally enhancing the capacity and volumes of product flows.	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.

#	Problem Areas	Conceptualization	Articles
4	**IM**	Handles demand uncertainty by re-locating stocks and transporting relief items to depots (e.g., HRD units) established in disaster areas.	Blecken et al., 2010; Fereiduni and Shahanaghi, 2017; Kristianto et al., 2014; Rawls and Trunquist, 2010; Rottkemper et al., 2011.
5	**Transp**	Mobilizes relief items (logistics, food, clothing, medicine, etc.) and emergency resources from one place to another within a shorter lead time by re-using vehicles to cover new routes within the same period in one attempt.	Barbarosoğlu and Arda, 2004; Kristianto et al., 2014; Moreno et al., 2016.
6	**Sched**	Considers optimally scheduling and assigning resources and personnel to specific tasks to achieve maximum equity or fairness in supplying relief items to the demand points.	Han et al., 2010; Rolland et al., 2010.

3.2.1 Problem Areas in HL Operations

Humanitarian Relief Distribution. This problem area concentrates on the effective distribution of demanded relief goods in a time-critical setting (Rahman et al., 2019). It encompasses a large variety of decision-making problem formulations: ten decision objectives, 13 decision variables, and 12 decision constraints. According to the reviewed literature, researchers in this problem area primarily focus on quickly providing essential relief goods to the demand points (Nolz et al., 2010; Viswanath and Peeta, 2007) by minimizing related costs (operational, resource, and penalty). To serve maximum demand in the determined distribution centers, HRD operations must remain uninterrupted (Liberatore et al., 2014; Rancourt et al., 2015). To accomplish this, the distribution network must adequately be recovered and optimized (Chunguang et al., 2010; Liberatore et al., 2014). However, for faster and equitable responses towards multiple demand points, decision-makers should be able to find and use different strategies to identify critical relief goods and prioritize them based on necessity (Ransikarbum and Mason, 2016; Rottkemper and Fischer, 2013; Tofighi et al., 2016). Various scenarios can be generated and applied to identify such rules for faster and well-founded decision-making (Rottkemper and Fischer, 2013; Tofighi et al., 2016).

Facility Locations. This problem area has received the most research attention. Researchers in it intend to establish necessary warehouses at easily accessible places (near disaster areas). So, essential relief goods can be rapidly delivered to the demand points or distribution centers (Fereiduni and Shahanaghi, 2017; Jabbarzadeh et al., 2016). The optimizing models for this problem area combinedly enlist five decision objectives, 17 decision variables, and 11 decision constraints. By proposing different models, researchers emphasize maximizing coverage and beneficiary satisfaction, while minimizing total and operational costs. Researchers express that it is important to solve FL issues before concentrating on other areas. For example, Tofighi et al. (2016) consider planning HRD after identifying locations and capacities for central warehouses and local distribution centers in a relief network. Moreno et al. (2016) integrate issues with FL, while solving transportation problems by reusing vehicles in emergency logistics. However, the consensus is that facility locations should be carefully selected to optimally route emergency relief goods (Han et al., 2010).

Relief Supply Chain. This problem area focuses on maintaining networks for procuring and supplying relief goods for immediate disaster response (Fahimnia et al., 2017; Nagurney et al., 2011; Rahman et al., 2019). It recommends six decision objectives, 17 decision variables, and 11 decision constraints. For faster supply delivery, researchers concentrate on finding a shorter distribution network. However, identifying such networks, including selecting potential suppliers and logistics plans, is challenging for decision-makers (Hu et al., 2017) because they must also minimize various costs (total, average, operational, and psychological). Thus, from procuring products to delivering them, researchers and practitioners perform various complex activities, which affect decisions in HSC modeling. Therefore, for rapid and timely humanitarian response to any disaster, situation-appropriate HSCs should be used or followed and maintained. Nagurney and Nagurney (2016) prefer prioritizing associated demand points, while Sheu and Pan (2014) suggest earlier detection of inappropriate emergency facilities or inefficient resource allocations in a centralized network. Furthermore, for better response, the structure of responding organizations and their policies for warehousing, allocating, and distributing relief materials must be evaluated (Chang et al., 2007).

Inventory Management. This problem area concentrates on managing and relocating inventories (i.e., relief goods) to depots as needed (Blecken et al., 2010; Rawls and Turnquist, 2010; Rottkemper et al., 2011). Thus, it contributes to addressing demand uncertainties (Rahman et al., 2019). This problem area consists of two decision objectives, nine decision variables, and 11 decision constraints. To optimally allocate and relocate relief goods, it stresses cost minimization (i.e., total operating costs, penalty costs for unused inventories, and weighted shortage costs). However, due to the operation of multiple distribution centers, as well as supply and demand uncertainty in these centers, decision-makers face complex planning and decision-making problems. Solving these issues demands finding the most accessible emergency supply locations for allocating and relocating necessary resources to distribution centers in need (Blecken et al., 2010; Fereiduni and Shahanaghi, 2017; Rawls and Turnquist, 2010; Rottkemper et al., 2011). Multiple distribution centers can be opened in a disaster area to handle higher fluctuations in demand and/or supply by relocating inventories during ongoing humanitarian operations (Blecken et al., 2010; Rottkemper et al., 2011). However, this is not a simple task; it may cause complex planning problems. While allocating relief materials, decision-makers must have precise information about warehouses, their available capacities, optimal locations, and accessibility (Fereiduni and Shahanaghi, 2017; Rawls and Turnquist, 2010; Rottkemper et al., 2011).

Transportation. This problem area focuses on mobilizing necessary resources and relief goods to demand points (Rahman et al., 2019). Researchers also seek to achieve shorter lead times by covering new routes in a single trip (Barbarosoğlu and Arda, 2004; Moreno et al., 2016). This problem area encompasses two decision objectives, six decision variables, and eight decision constraints. To deliver relief materials to demand points, the reviewed models concentrate on minimizing total process cost and traveling time. Therefore, proper transport planning is necessary for faster relief delivery. Moreno et al. (2016) focus on enhancing the utility of transport planning by reusing allocated vehicles. They claim that vehicle reuse could improve the overall performance of relief operations by saving resources and providing better service. For optimized transport routing, it is necessary to consider randomness, not only in demand, but also in supply and route capacity (Barbarosoğlu and Arda, 2004; Kristianto et al., 2014).

Scheduling. This problem area emphasizes assigning resources to specific tasks for effective HRD (Hans et al., 2010; Rahman et al., 2019; Rolland et al., 2010). It involves three decision objectives, six decision variables, and eight decision constraints, and it focuses on minimizing total processing cost, associated penalty cost, and travel distance to bring relief goods to the targeted demand points. Although this literature inquiry identified little research attention being given to this problem area, it plays a vital role in humanitarian operations because responders must make decisions about assigning assets and skilled personnel to perform specific functions (Rolland et al., 2010). Lacking the necessary resources would make the distribution process poorly executed and create complex and chaotic situations for responders. In addition, vehicle scheduling affects the warehouse selection process since the operation must align with the connected roads' capacities and their dynamic flow conservation (Han et al., 2010). Possibly for this reason, Rolland et al. (2010) recommend considering operational constraints in resource-constrained scheduling (resources and personnel), such as workload and labor requirements, precedence constraints, resource availability, and critical deadlines.

3.2.2 Analytical Discussion

This investigation showed that HL researchers mainly focus on solving problems for individual problem areas, and, among the six identified problem areas, FL receives the most attention. This problem area is sometimes incorporated in other areas to produce effective solutions by sharing various decision factors. However, since HRD involves all objectives that are common across problem areas, this kind of sharing happens with all problem areas, not only with FL. So, for efficient and effective HRD operations, decision-makers must also consider achieving intended objectives in other problem areas. To illustrate such influences to HRD–DM, consider an evident phenomenon: if relief goods cannot be transported by reducing cost and travel time to the destination, HRD will be hampered by the delayed and costly response to the demand points. Therefore, the overall performance of humanitarian operations will be affected, which includes each of the problem areas involved.

On the other hand, this analysis also identified the use of variances for similar decision factors. When a topic is considered a targeted objective in a problem area, it is recognized as a constraint or a variable in other problem areas. For example, based on investigating contexts, decision-making in the RSC considers *travel distance* as a minimizing objective, whereas FL understands it as an influencing variable, and HRD finds it to be an affecting constraint. By quantifying such interconnectedness, influential thresholds can be generated to determine the level of involvement of other problem areas while developing models for a specific one. This horizontal analysis is exploited in Paper 4 to propose an operational ecosystem for understanding the concurrencies between problem areas and their influences on

HRD–DM. The identified decision factors for HRD were also empirically validated to find correlations between decision factors and suggest balanced use of those factors in decision-making.

To ensure effective HRD, HL operations encompass three decision-making levels: strategic, tactical, and operational (Blecken, 2009; Peres et al., 2012). Blecken (2009) defines the strategic level as determining process capacity (i.e., deciding its structure, resource allocations, and responsibilities). Blecken (2009) positions decision-making/planning tasks at the tactical level, which are to be implemented/executed at the operational level. To understand the hierarchical structure of decision-making in HL, I further analyzed the mapping via the reference task modeling technique proposed by Blecken (2009). After analysis, overlapping decision-making situations were identified for all problem areas. When problem areas were considered as the requirements for humanitarian operations, the issues in Transp, IM, and RSC were entitled to be discussed at both strategic and tactical levels. Furthermore, HRD issues captured concentration from every level of decision-making, while FL issues were mainly addressed at the strategic level. Lastly, decision-makers at tactical and operational levels handle Sched issues to make relief goods ready for distribution. This vertical analysis, by more fully defining the process, can assist decision-makers at each level when making potential HRD decisions.

3.3 Chapter Summary

This study contributes to both decision-making types: theoretical and practical. It enriches the HL 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. Researchers can exploit these factors and the proposed ecosystem (see Paper 4) to offer models for assisting practical decision-making in the field. By considering the findings of this study, more elaborated research can be conducted at an operational level to distribute relief goods to disaster survivors in the shortest possible time. Thus, higher satisfaction from beneficiaries can be achieved, with minimized deprivation and psychological cost.

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4 Research Design

HL operations, in a real-world setting, are always complicated since ineffective or unsuccessful actions may result in increased social tension, enormous sufferings, and/or even higher death tolls. Therefore, complex research in this domain should have conscious scientific reasoning (Bryman and Bell, 2015) and should be conducted systematically (Gray, 2014). This detailed discussion of design rationale will facilitate readers by offering them a better understanding of the research design (Walsham, 1995) to track my findings (Miles and Huberman, 1984). Thus, this research may be more widely accepted among IS professionals and other research communities (Hevner, 2007).

This chapter presents the approach taken to answer the RQs introduced in Chapter 1. By following Creswell (2009), the discussion is divided into three consecutive sections: philosophical worldview, strategies of inquiry, and research methods. The initial section argues the philosophical foundation of this research. Its methodological choices are summarized in the next section. The final section describes the study's data collection, analysis, and validation processes, as well as the issues inherent in validating the research design and how they were addressed. Figure 4.1 overviews the research design.

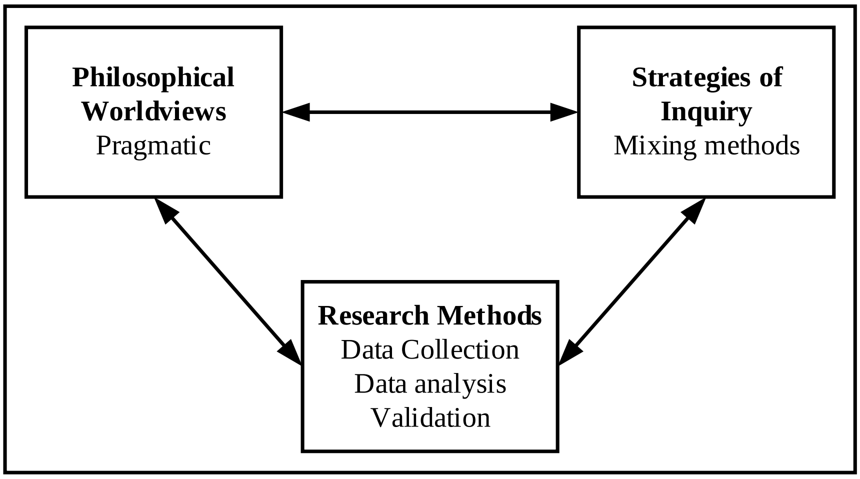

Figure 4.1: Research design (adapted from Creswell [2009])

4.1 Philosophical Worldviews

The philosophical analysis helps researchers develop an overall understanding of a research field, its roots, current developments, and future extensions (Artz, 2013; Hirschheim and Klein, 1989). Such an analytical study on research philosophy is vital for IS research as it accepts research methods and paradigms from other disciplines (Wade and Hulland, 2004). Although positivist and interpretive paradigms dominate IS research (Hirschheim and Klein, 2012; Orlikowski and Baroudi, 1991), critical realism and pragmatism are, however, also widely used (Mingers et al., 2013; Omland and Thapa, 2017; Goldkuhl, 2012). Paper 3 elaborately examines and discusses the philosophical underpinnings of these paradigms. They are conceptualized in Figure 4.2 and briefly discussed in the rest of this section. However, due to its philosophical description, pragmatism cannot be accommodated in Figure 4.2 (see Paper 3 for details), but it is subsequently described to explain this dissertation's philosophical stance.

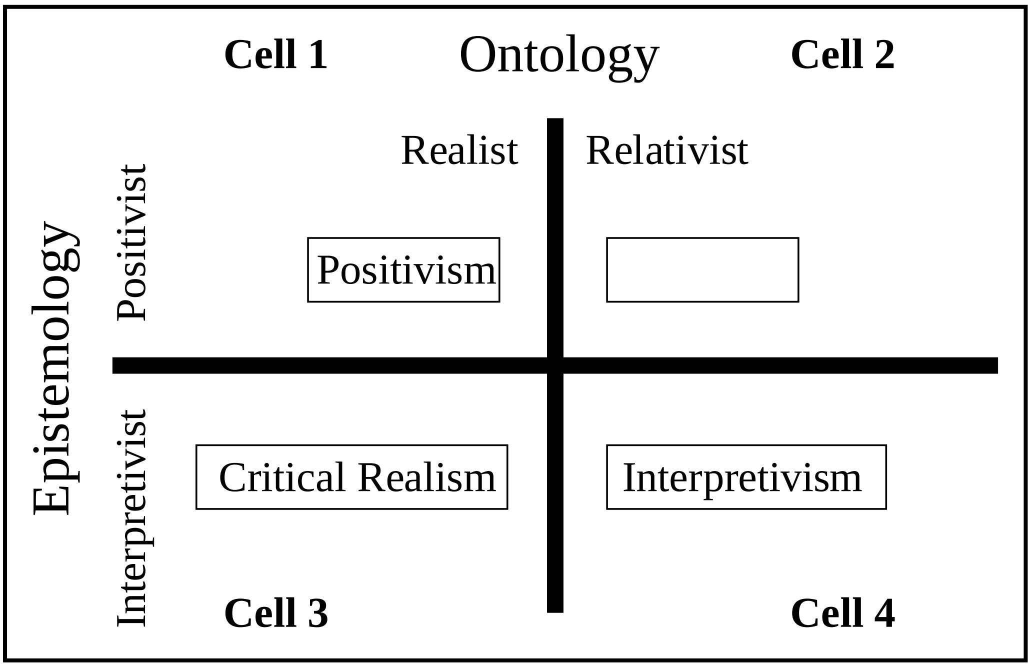

Figure 4.2: Paradigmatic discourses (adapted from Poonamallee [2009])

Cell 1 in Figure 4.2 represents pure positivism with a *realist ontology*, which studies social reality in scientific ways (Bryman, 2003) and uses a *positivist (or objectivist) epistemology* to achieve some law-like generalizations (Saunders et al., 2009). Researchers in this paradigm follow *quantitative research methodologies* (Chilisa and Kawulich, 2012; Guba and Lincoln, 1994; Kaplan and Duchon, 1988) to produce *axiologically value-free* outcomes (Scotland, 2012). Researchers also strictly abide by the prescribed procedures or principles to reach the truth.

Cell 2 encompasses *relativist ontology* and *positivist epistemology*. The research in this paradigm deals with different contexts through specific modes of knowledge acquisition. Researchers apply similar approaches to understand different realities. However, no paradigm has been identified to satisfy the philosophical understanding of this quadrant.

Cell 3 is comprised of the *realist ontology* and the *interpretivist epistemology*. Here, researchers believe in a single, fixed, grounding reality. Unlike positivists, they believe there are multiple ways to find that truth, out of which the best approach is chosen. This paradigm incorporates research with critical realism, which focuses on identifying the causality of the addressing problem (Mingers et al., 2013; Omland and Thapa, 2017). It mixes qualitative and quantitative methods to become axiologically value-laden.

Cell 4 represents interpretivism, which is *ontologically relative* and *epistemologically interpretive*. Interpretive researchers do not believe in the existence of truth. To them, the reality is socially constructed (Creswell, 2003; Walsham, 1995) and changes based on the context. Thus, ontologically, this paradigm has at least two realities. To understand an individual's behavior and experience, interpretivism closely observes the subject's activities in a natural setting and, thus, accepts subjectivism as its epistemological stance (Chilisa and Kawulich, 2012). Researchers in this stream prefer qualitative methods to study the targeted phenomena and make their contributions axiologically value-bound and value-laden (Chilisa and Kawulich, 2012; Ihuah and Eaton, 2013).

In the pragmatic paradigm, researchers share concerns from both positivism and post-positivism to address problems with practically implementable solutions (Goldkuhl, 2004; Ihuah and Eaton, 2013). They mainly concentrate on supporting humans in problem-solving, not just finding the truth (Powell, 2001). Pragmatics believe in multiple realities and in many different ways of interpreting the world (Saunders, 2009). Hence, formulating RQs is an important determinant of the research philosophy in this continuum (Giacobbi et al., 2005). To answer those RQs, pragmatic researchers adapt to philosophical assumptions modified over time and are placed in a different area of the continuum (Collis and Hussey, 2013). Thus, pragmatism becomes a right candidate for humanitarian DSS research (Rahman, 2018).

This study chose pragmatism as its philosophical worldview for advancing DSS research in HL and proposing practical solutions to decision-making problems.

Based on the contextual requirements, the ontological and epistemological understanding of these problems causes paradigmatic shifting. When studying DSS in HL, the dynamics of choosing philosophical components in the activated contexts can be supported by pragmatic discourse. The reality of DSS cannot be defined as socially constructed. Along with user-defined requirements, every DSS must satisfy some developmental rules before achieving the final product (an IS artifact). Following adaptive principles, developing such a system requires a modified understanding of reality. However, the development process is not straightforward; it involves iteration to reveal meaning and strengthen its ontological stance (Goldkuhl, 2012; Ihuah and Eaton, 2013; Morgan, 2014). Due to its tendency to solve practical problems, DSS research epistemically adopts either (or both) objective and subjective views of knowledge creation (Giacobbi et al., 2005). Hence, researchers in this domain mix quantitative and qualitative methods for data collection and analysis (Giacobbi et al., 2005; Pansiri, 2005). So, values in DSS research become axiologically value-achieving and play a significant role in answering RQs. Paper 3 can be consulted for a detailed discussion on pragmatism and its selection for this research.

4.2 Strategies of Inquiry

Identifying appropriate inquiry strategies is essential for any research before starting the project. Researchers must have a clear view of the chosen study, data collection, and data analysis methods, as well as possible findings (El-Gazzar, 2016). From pragmatic viewpoints, researchers can combine positivist and interpretivist stances to answer a question in a single study (Rahman, 2018). Thus, pragmatic researchers enjoy the freedom to choose research methods, techniques, and procedures to identify working solutions (Creswell, 2007; Morgan, 2014). They are allowed to use either (or both) qualitative and quantitative methods, depending on what suits the problem of inquiry (Holden and Lynch, 2004).

Since humanitarian DSSs are embedded in practical implementation (*what works*), system modeling and development (in the latter stage) largely depend on requirements elicitation, analysis, and validation (Khan et al., 2014). Thus, mixing qualitative and quantitative methods is necessary. In addition to qualitative interviews, an SLR, according to Snyder (2019), can also be considered a qualitative research method for collecting data if a strict process is followed to obtain articles and qualitatively assess them. Domain experts and practitioners can validate such findings through quantitative surveys, through which they can provide feedback on what I may have overlooked. By qualitatively analyzing expert recommendations, researchers can enrich their findings.

To address the RQs, I, by applying the presented strategy, mixed qualitative and quantitative methods for data collection and analysis. After gaining an adequate understanding of the research problem, the literature was systematically collected and reviewed (reported in Chapter 3). I then qualitatively assessed the studies to identify the requirements for modeling the DSS: interconnected problem areas and their decision factors. A panel of domain experts was recruited to validate the findings through a Delphi study (see Section 4.3). While designing the survey, I included both open- and closed-ended questions. The panelists ranked the findings from the SLR to answer the closed-ended questions, and, in answering the open-ended questions, they provided their feedback on missing but important decision factors in plain language. Finally, online and face-to-face interviews were strategized. Data analysis was performed both statistically and textually.

4.3 Research Method

Academic research cannot individually provide useful decision-making support to humanitarian operations like practical problems, especially for effective and efficient HRD (Oloruntoba, 2010). Field experts must practically evaluate research findings. Therefore, more empirical research is necessary to identify and assess an extensive and comprehensive set of decision factors for HRD–DM (De Leeuw et al., 2010; Richardson et al., 2016).

In disaster response, HDMs spend busy and chaotic working days procuring and distributing relief goods by tackling dynamic uncertainties. They usually have little time to participate in academic research. On the other hand, due to accessibility, financial, and time constraints, it is difficult for researchers to include multiple disasters in the same study (Baharmand et al., 2017). According to Baharmand et al. (2017), covering even a single event sometimes becomes difficult. Since disasters usually provide shorter preparation time, abnormal field conditions, limited resources, and travel restrictions, key informants and severely affected areas remain inaccessible for interviewing and observation. Therefore, to balance the harm–benefit by not disturbing relief operations through field trips (O'Mathúna, 2015), I emphasized validating my SLR findings by forming an expert panel, members of which had extensive working experience in responding to natural disasters.

I employed the ranking-type Delphi method for this explorative study to list and prioritize critical factors for HRD–DM (Gossler et al., 2019; Richardson et al., 2016). Twenty-three experts from academia and practice were contacted and surveyed electronically. To be grounded in current practice and to achieve rich and in-depth information regarding the domain of interest, only six experts were interviewed (Meuser and Nagel, 2009). Again, I integrated both quantitative and qualitative data to make useful and credible inferences (Caracelli and Greene, 1993).

This section presents the research method used for this study's data collection, data analysis, and validation. An overview of the method is demonstrated in Figure 4.3 and described subsequently. The data collection phase included all steps for accumulating decision factors from the SLR and practice through the Delphi study. Panelists' responses in the Delphi survey were statistically analyzed during the data analysis phases to validate the identified decision factors, determine what should occur in the next round of the survey, and inform responders about the results of the previous round. The analytical results were then used to create a prioritized list of decision factors and validate the operational ecosystem for HRD–DM. Based on the collected data and their analyses, this section finally validates the Delphi study.

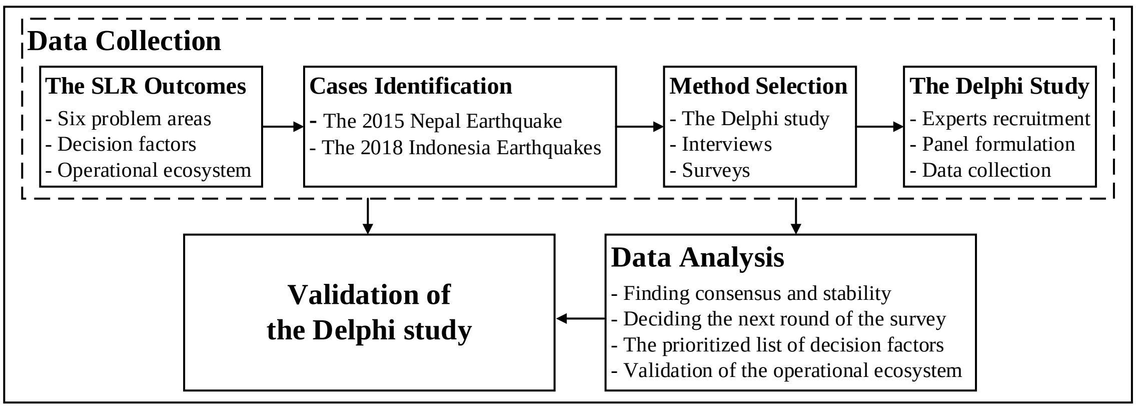

Figure 4.3: Research methods for this study

4.3.1 Data Collection

The SLR Outcomes. As reported in Chapter 3, I conducted a systematic and rigorous literature review to collect, analyze, and synthesize the requirements for modeling the intended humanitarian DSS. The SLR resulted in six interconnected problem areas and their associated decision factors. Their effect on HRD–DM is examined in Paper 4 to frame HL as an operational ecological system.

Cases Identification. For empirically evaluating research work, identifying and assessing suitable cases is a difficult task. It demands, not only time, but also adequate efforts from researchers. Walsham (2006) suggests that researchers should choose the case(s) to study based on their investigating contexts, preferences, opportunities, and constraints. For useful data collection, it is necessary to select the appropriate case before contacting experts and proceeding further. Therefore, I chose the 2015 Nepal earthquake and the 2018 Indonesia earthquake cases to validate the requirements for modeling the envisioned humanitarian DSS. The selected cases are briefly described in the subsequent sections, whereas their prime characteristics that influenced such selection are presented in Table 4.1.

Table 4.1: Prime characteristics of the selected cases

#	Characteristics	Description
1	Recency and severity	Indonesia earthquakes 2018: 2,664 dead, 5,984 injured, and at least 910 million USD in economic loss. Nepal earthquake 2015: 8,790 dead, 22,300 injured, and at least 7 billion USD in economic loss.
2	The topography of the affected areas	Indonesia is an island country, whereas Nepal is mountainous. Access to the affected areas for distributing relief goods was much more difficult in these countries compared to flatter countries. Responders also faced liquefaction in Indonesia and severe landslides in Nepal.
3	Poor social infrastructures of these countries	In both countries, cities are built without considering the geography or disaster-resisting instructions.
4	Countries' financial conditions	Economic instability delays disaster responses and causes chaos, social tension, and desperate seeking of relief goods.
5	Overall management of complex relief operations	In-country rules and regulations limit access by international responders and, thus, hinder the assistance they would provide.
6	Availability of data and informants (from the researcher's viewpoint)	I recruited humanitarian responders working in the chosen disasters by exploiting personal, CIEM[18], and colleagues' networks. I connected with some important responders from well-known humanitarian organizations (governmental, non-governmental, and international)

[18] Center for Integrated Emergency Management (www.ciem.uia.no)

#	Characteristics	Description
		through a web search—for example, the AHA Centre[19], Lingkar[20], WFP[21], OCHA[22].

The 2015 Nepal Earthquake. Nepal experienced a mighty earthquake with a magnitude of 7.8, which struck Kathmandu and its surroundings on April 25, 2015. It toppled city structures, caused landslides, and started avalanches in the Himalayas. The government requested international assistance in the early hours after the earthquake. Over 60 countries responded to the call with humanitarian assistance and emergency relief; the United Nations and other international agencies also took part in this operation (Baharmand, 2018). The initial needs included search and rescue (SAR), medical services and supplies, clean water and sanitation, food, nutrition, emergency shelter, logistics, and telecommunications (Baharmand, 2018). The government received support from 134 international SAR teams to rescue around 12,247 survivors by air and land (NPC, 2015). However, because Nepal is such a mountainous country, distributing relief items was not easy. The responders faced many challenges; important examples are articulated in Table 4.2 (Baharmand et al., 2016; Collins and Jibson, 2015; Paul et al., 2017; Snellinger, 2016).

Table 4.2: The challenges faced in the Nepali and Indonesian cases[23]

#	The 2015 Nepal Earthquake	The 2018 Indonesia Earthquake
1	Political instability	Assess damage, impact, and demand
2	Access the affected communities	Access the affected areas
3	Limited logistical support	Limited community participation
4	Discrimination issues	Rumors
5	Lack of coordination	Lack of coordination
6	Geography of Nepal	Medical support
7	Custom clearance	Psychological support
Note: the salient challenges in both cases are listed here, not compared.		

The 2018 Indonesia Earthquake. The last half of the year 2018 was devastating for Indonesia. The inhabitants of Lombok, Mataram, and Sulawesi faced a series of earthquakes and numerous aftershocks of higher magnitude (maximum 7.5) from July to December. The government of Indonesia received assistance offers

[19] AHA Centre – Emergency Operation Centre (www.ahacentre.org)

[20] Perkumpulan Lingkar (www.lingkar.or.id)

[21] United Nations World Food Programme (www.wfp.org)

[22] United Nations Office for the Coordination of Humanitarian Affairs (www.unocha.org)

[23] The order has no deeper meaning.

from 29 countries, including offers to provide specific humanitarian needs on the ground, such as air transportation, tents, water treatment, electric generators, and financial donations (IHCT[24], 2018). Through the AHA Centre, the National Disaster Management Authority (BNPB[25]) received assistance offers from 55 international humanitarian organizations to support the 2.4 million affected people across nine cities in Central Sulawesi (AHA, 2018). Jointly formed response teams led by the hosting governments were deployed for rescue, evacuation, and HRD operations (IHCT, 2018). While dealing with such complex disaster situations, response teams faced challenges (listed in Table 4.2), which hindered faster HRD–DM (AHA, 2018; IFRC, 2018a; IFRC, 2018b).

Method Selection. Since it provides the capability to elicit experts' opinions, the Delphi method was used in this study to validate the comprehensive set of identified decision factors, which motivate and influence HRD more generally. Although it is not widely exploited in HL research (Gossle et al., 2019), MacCarthy and Atthirawong (2003) argue that the Delphi method is suitable for studying and understanding decision-making factors. For conveniently distributing relief goods in developing countries, Cottam et al. (2004) use this method to assess the potential benefit of outsourcing trucking activities. Richardson et al. (2016) also incorporate a similar technique to investigate affecting factors for global inventory prepositioning locations.

Through the first round of the Delphi survey, experts reflected on the importance (via rating) of each attribute in the decision-making process (Hasson et al., 2000). In the present case, the score was considered unbiased as responding experts were located at a distance from one another and were expected to have no communication while answering the survey questionnaires. Experts were also given the opportunities to submit their opinions remotely, know others' ideas in general, and re-evaluate their responses (Ogden et al., 2016). They could even propose new decision factors from the field, which were then validated by other panel members in the second round of the survey. Those who found it difficult to answer the survey after receiving its questionnaire were given the opportunity to attend qualitative interview sessions to provide their

[24] Humanitarian Country Team in Indonesia (https://reliefweb.int/organization/hct-indonesia)

[25] National Disaster Mitigation Agency (www.bnpb.go.id)

insightful inputs. The conducted Delphi study is elaborated in the subsequent sections, and its results are articulated and discussed in Paper 5.

The Delphi Study. The overall Delphi study is illustrated in Figure 4.4, which presents, not only the panel formation, but also the Delphi study design. Each demonstrated step is explained subsequently.

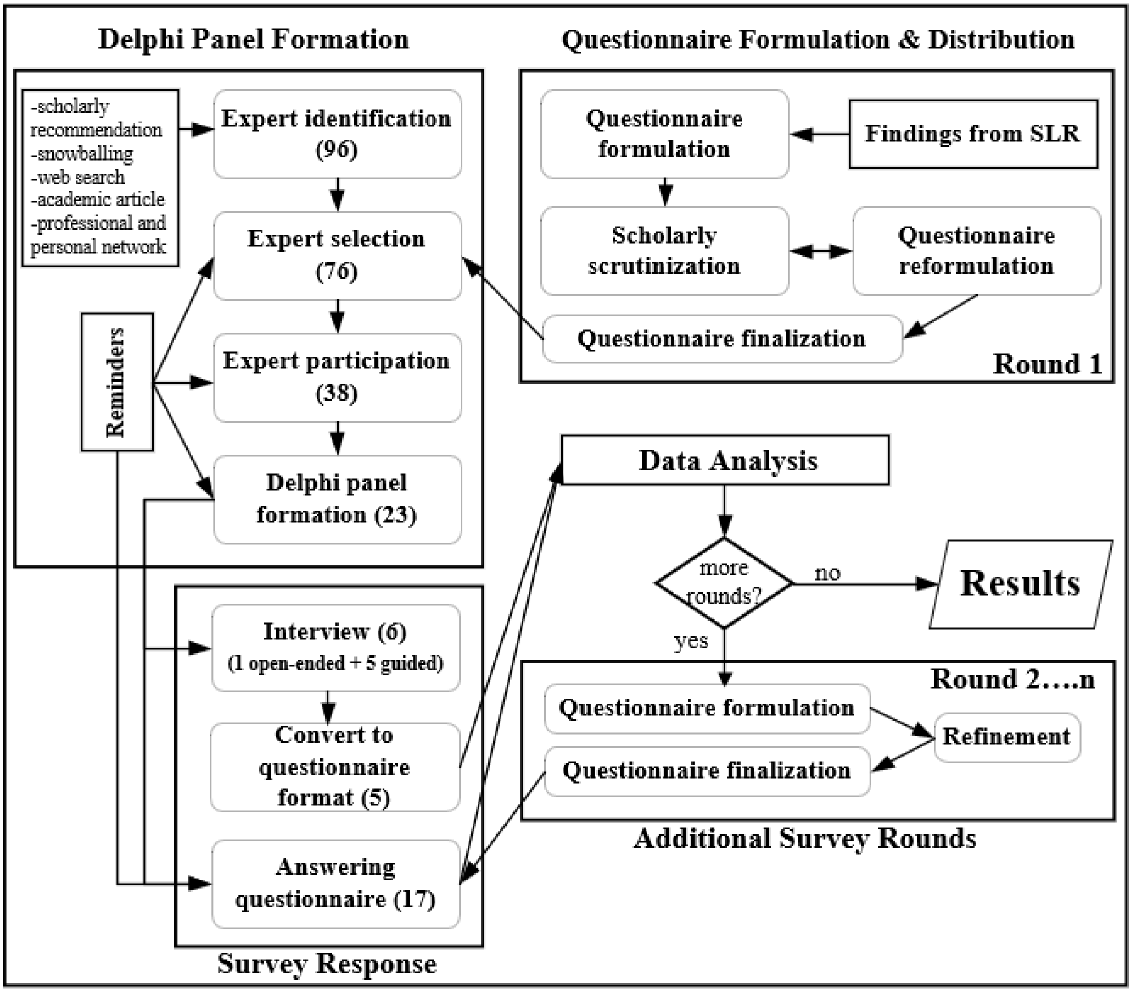

Figure 4.4: The process model utilized in this Delphi study

Experts Recruitment and Panel Formulation. Selecting appropriate panel members is the initial step of the Delphi method (Päivärinta et al., 2011), and it is a vital and challenging task (Okoli and Pawlowski, 2004; Stewart et al., 2017). Most Delphi users recommend recruiting experts from the targeted research area credible to the intended audiences (Melander, 2018; Powell, 2003). Their working background, knowledge, experience, judgment, and opinions lead to better responses to research inquiries (McMillan et al., 2016; Paré et al., 2013). For this study, I defined an expert as an HL researcher or practitioner with considerable and personal experience in HRD (Gossler et al., 2019). To identify potential experts, I used departmental, university, research groups', colleagues' and personal networks. Afterward, I accessed the already recruited experts' networks to get more informants onboard. To extend the panel-size, I also searched for experts in academic articles and for practitioners on the web, such as the AHA Centre, BNPB Indonesia, Logistics Cluster,[26] Humanitarian Response,[27] Mercy Malaysia,[28] and ReliefWeb.[29]

Thus, a contact network was established with 96 HL experts from both academia and practice. However, due to the lack of updated contact information, some of these experts were unreachable. As soon as a tentative list of reachable participants was ready, I wrote motivating emails to the potential expert recruits, summarizing the research concentration and other related information. Each expert was requested to suggest potential participants in their networks. The nominated experts were also contacted and requested to participate. All experts were then listed into a personal system and anonymized for further processing. This process resulted in 76 potential participants for the first round of the survey (see the next section for detail). The questionnaire was sent to them electronically. After understanding the research agenda, 38 experts affirmed their participation in the study. However, when the extensivity of the survey became more explicit, 23 heterogeneous experts from around the globe agreed to participate. The finalized Delphi panel is presented in Appendix E. All panelists are introduced along with their affiliations, professional backgrounds, disasters for which they contributed aid (specific or general), countries, involvement in this study, and method of networking. They are anonymized and identified with unique codes: P1 to P76.

Data Collection. This study included two Delphi rounds with two questionnaires. The first questionnaire was designed by mixing data collection approaches - quantitatively validating the decision factors from the SLR and qualitatively collecting new ones from the respondents. The second questionnaire followed a quantitative approach to inform the panelists about the results from the previous round. The

[26] www.logcluster.org

[27] www.humanitarianresponse.info

[28] www.mercy.org.my

[29] www.reliefweb.int

experts then validated the new decision factors collected from the first round. Both questionnaires are respectively presented in Appendix F. Besides, six participants were qualitatively interviewed to explore further expert knowledge on the related topics (Meuser and Nagel, 2009). They were provided in-depth, practical information regarding HRD–DM. These data collection methods are described below.

Questionnaire 1. Since it promoted survey participation, this initial questionnaire began with a concise but insightful description of the research motivation. To provide participants with a thematic understanding of the survey, I adequately explained the specific terms used in the questionnaire. The respondents also received the instructions necessary to rate the incorporated decision factors. The questionnaire was constructed with four individual sections: A to D. In section A, the survey captured profiling information for each respondent. They also provided their consent to data processing here. Sections B to D contained validating factors for ten decision objectives, 13 decision variables, and 12 decision constraints, respectively. Furthermore, to understand the depth of influences and assess the HL ecosystem, the experts were requested to identify how the other five problem areas (*FL, IM, RSC, Transp,* and *Sched*) affect each decision factor of HRD. However, these questions were optional so that the research could receive faster responses. The questionnaire underwent several rounds of evaluation from four Professors, who have extensive experience in developing and utilizing survey questionnaires for conducting Delphi studies in multidisciplinary research environments.

Questionnaire 2. The second questionnaire of this study was designed to report the findings from the initial Delphi round (Hsu and Sandford, 2007). It included the validation results for the decision factors from the SLR and the new decision factors recommended by the respondents. The primary assembling structure of the first questionnaire was adapted to create this questionnaire. Here, the panelists were also provided with the analytical results from the previous questionnaire: *average rating, percentage of overall agreement and disagreement, overall ranking,* and *preliminary consensus*. They were then given the opportunity to modify their earlier scores if they wished after seeing the analytical results. Following an approach similar to that in the first round, in this questionnaire, the experts mainly validated the newly incorporated decision factors.

Scores from both rounds underwent a similar statistical analysis to confirm the achievement of ultimate stability and consensus.

Interviews. Participants were offered the flexibility to choose between answering survey questionnaires or participating in a physical or online interview. Because they found the survey challenging to understand or time-consuming to answer, six panelists decided to be interviewed. Out of these interviews, one was a physical, open-ended interview, and the rest were online, guided interviews conducted via Skype and WhatsApp software. On average, these interviews lasted over an hour. However, in some cases, the online, guided interviews ended as informal, open-ended discussions about HRD processes and problems. With the interviewees' permission, all interviews were recorded on an audio recorder and transferred to my working computer for further processing, such as transcription and coding. To transcribe the recorded interview audios, I adapted the *gisted transcription* method presented by Evers (2011). This method involves comparing notes taken during the interview with the understanding gained while listening to the tape. Thus, necessary correction, modification, and updating can be made in the detailed notes. Afterward, each gisted transcript was coded by adapting the steps proposed by Díaz Andrade (2009): (i) creating and assigning categories, (ii) exploring the connection between them, (iii) concluding with an integrating core. While transcribing and coding, I carefully listened to the recorded interviews and took necessary reflection notes to understand their tone and emphasis on specific decision factors (Moe, 2015). These notes assisted me in interpreting the experts' thoughts to conceptualize reasonable conclusions. To confirm my interpretations, I listened to the interviews again and systematically searched for the quotes (Moe, 2015). Afterward, with the interviewees' permission, the codes were used to answer the questionnaire, and, thus, the unstructured interview data was converted into structured survey data. The numeric trends of qualitative data can be merged with the specific details received from quantitative data to identify new behavior for the system (Hanson et al., 2005). These interviews not only provided important qualitative data on responding to different disasters, but also suggested future research avenues from practical viewpoints.

4.3.2 Data Analysis

To generate a prioritized list of merged decision factors (from the literature and practice), data from both Delphi rounds were analyzed. The statistical analysis, its results, and the related discussion on decision factors are detailed in Paper 5. To avoid redundancy, this section presents and discusses the finalized list of decision factors. Before this discussion, the selection and prioritization process is described by demonstrating how consensus and stability were found and how two rounds of the survey were decided. Afterward, I present the validation of the ecological system for HRD–DM reported in Paper 4. In doing so, I discuss how the panelists' reflected on interconnections between HRD and other problem areas.

Consensus and Stability Identification. For data analysis, Delphi studies depend on achieving stability and consensus (Toepoel and Emerson, 2017). Identifying *general agreement* or *consensus* about a decision factor is a valuable component for knowing experts' opinions on accepting or denying specific decision factors in the decision-making process (Cottam et al., 2004; Heiko, 2012; Linestone and Turoff, 1975). To identify those decision factors that achieved consensus, I utilized Kapoor's (1987) *Average Point of Majority Opinions* (APMO) technique (see Equation 1). The achievement of agreement or disagreement in this method is determined based on whether the values (calculated as below) are above the APMO cut-off rate.

$$APMO = \frac{majority\ agreements + majority\ disagreements}{total\ opinion\ expressed} X100 \qquad (1)$$

To examine the consistency (or stability) of each decision factor, I calculated the *coefficient of variance (CV)* in both Delphi rounds and compared them after the second round. *Kendall's concordance coefficient (W)* in SPSS software was used to identify the degree of agreement among panel members. To represent agreement and disagreement, Kendall employs a scale ranging from 0 to 1, where *W=0* expresses a perfect disagreement, and *W=1* constitutes a definitive agreement. However, as it is difficult (or sometimes impractical) to achieve ideal understanding, *W=0.7* is considered a higher level of general agreement in Delphi studies (Schmidt, 1997). Based on the findings for both concepts, I decided to conduct only two Delphi rounds of data collection and analysis (Dajani and Sincoff, 1979).

The Next Survey Round Detection. The first round of the survey was conducted between December 2018 and February 2019. A total of 23 HL experts participated in this round, 17 answered the questionnaire by rating the provided list, and six were interviewed. In addition to assessing the listed decision factors, 13 out of 23 panelists identified (new) decision factors absent in the provided list. Their scores were used to determine the elements of the next survey round, as English and Kernan (1976) suggest the ratio of $0<CV\leq 0.5$ as the level of stability achievement or the threshold for stopping further rounds. Because each decision factor category had very low *Kendall's W* (0.181 for objectives, 0.133 for variables, and 0.26 for constraints), and because some attributes represented $CV\geq 0.5$, I found it logical to roll the second round of the survey.

The second round was conducted in March 2019. As the interviewed panelists reported busy working hours and provided adequate information in the previous round, they were not included in this round. Therefore, I rolled the survey among the 17 panelists, 13 of whom responded. The analytical results from the previous Delphi round were shared with all panelists in this round (Aljamal et al., 2016; Bygstad and Munkvold, 2010). They were also asked to rate the new decision factors: three decision objectives, 13 decision variables, and ten decision constraints. All decision factors in this round achieved a reasonable degree of agreement: $CV\leq 0.39$. To determine whether further survey rounds should be conducted, the CV values from both rounds were compared. The calculated absolute *CV difference* was ≤ 0.26 for decision factors in every category. There were significant improvements (although still not high) in *Kendall's W* as well: 0.194 for objectives, 0.213 for variables, and 0.470 for constraints. Thus, the stability in the general agreement was defined, and, hence, rolling for additional survey rounds was terminated (Dajani and Sincoff, 1979; El-Gazzar et al., 2016).

Prioritization of Decision Factors. When accumulated, the number of listed decision factors for HRD–DM was substantial: 13 (10+3)[30] decision objectives, 26 (13+13) decision variables, and 22 (12+10) decision constraints. However, suggesting such an extensive list to decision-makers is impractical and challenging to manage in the crucial responding time. Hence, I attempted to generate a prioritized list by accumulating top rated decision factors from literature and practice. In doing so, I further filtered the consensus-achieving decision factors from the literature by determining whether each received an over 80% vote in both Delphi rounds

[30] (10+3) -Ten decision factors from the literature and three form experts' preferences. Same convention for rest of the calculations in this paragraph.

and was highly ranked by the percentage of accepted majority. For decision factors from practice, I investigated whether each secured consensus with over a 90% vote in the second Delphi round and was highly ranked by the *Mean Rank* from SPSS. Thus, I ultimately recommended 6 (4+2) decision objectives, 8 (5+3) decision variables, and 8 (5+3) decision constraints as the most influential decision-making factors for HRD. Table 4.3 lists those decision factors, along with the percentage of the vote each received.

Table 4.3: The most influential decision factors for HRD

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

It is important to note that decision-making during large-scale natural disasters is typically highly contextual, and decision-makers face severe uncertainty in information gathering, processing, and implementation (Rahman et al., 2019). Therefore, to receive operational benefits, they should keep track of all the listed decision factors (see Paper 5) instead of just searching for the top ones (Rahman and Majchrzak, 2019). If consulted, the entire list of decision factors will support them in visualizing and understanding the changes and help them quickly identify relevant points necessary for making faster HRD decisions.

Validation of the Operational Ecosystem. Out of 23 panelists, 16 attempted to evaluate the operational ecosystem for HRD–DM. In the first questionnaire, they were requested to mark (based on their experience) the problem areas that must be considered when using each factor for HRD decisions. For a problem area to be considered essential for a specific HRD–DM factor, I required it to achieve a response threshold of 50% (Heiko, 2012).

After analyzing the responses, I observed a considerable change in the conceptual framework proposed in Paper 4. Except for the *FL* problem area, the number of common decision factors between *HRD* and the other problem areas increased, especially for *Transp* and *RSC*. This analysis resulted in a new ranking to inform decision-makers of the priority of each problem area for HRD decisions. It indicated that determining relief goods distribution is mostly affected by decision-making in transportation problems. Therefore, before deploying any HRD operation, the panelists suggested solving transportation problems first, whereas the literature prioritized finding and setting up facility locations. Safeer et al. (2014) support this empirical finding and prioritization because authorities always look for easily accessible points to set up facility locations for convenient transportation. The other changes can be explained similarly to justify the evaluation.

Interestingly, both rankings placed solving problems in the *RSC* in the second position. This finding suggests that *RSC* planning should be finalized immediately after solving problems with *Transp* or *FL* based on the operating contexts. Table 4.4 compares the quantified influences between findings from the literature and practice in the form of mathematical equations, which are explained in the rest of this section but are also respectively portrayed in Paper 4 and Figure 6.3.

Table 4.4: Comparison of quantified influences between literature and practice

Other Problem Areas	Literature-based (portrayed in Paper 4)		Experts' Preference (portrayed in Figure 6.3)	
	Quantified Influences	**Rank**	**Quantified Influences**	**Rank**
Facility Locations (FL)	O(3)+V(9)+C(6) = 18	1	O(5)+V(8)+C(4) = 17	3
Relief Supply Chain (RSC)	O(3)+V(6)+C(6) = 15	2	O(5)+V(9)+C(8) = 22	2
Scheduling (Sched)	O(2)+V(4)+C(6) = 12	3	O(6)+V(8)+C(2) = 16	4
Inventory Management (IM)	O(1)+V(5)+C(5) = 11	4	O(4)+V(4)+C(7) = 15	5
Transportation (Transp)	O(2)+V(3)+C(4) = 9	5	O(7)+V(11)+C(9) = 27	1
Abbreviations: O: decision objectives; V: decision variables; C: decision constraints				

The equations present the number of decision factors in the other problem areas that affect HRD–DM. To understand the message from Table 4.4, consider the *quantified influences from practice* for the *FL* problem area as an example. From traversing its equation (*O(5)+V(8)+C(4)=17*), it is evident that decision-making in *HRD* is interconnected with that in the *FL* problem area, sharing five decision objectives, eight decision variables, and four decision constraints (a total of 17 decision factors). Based on its total number of decision factors, it is ranked as the third problem area affecting HRD–DM.

4.3.3 Validation of the Delphi Study

All the data collection consequences were validated earlier in this chapter: case selection, Delphi panel formation, and study design (questionnaire formulation, interview conduction, consensus and consistency, and rounds). Therefore, now, I wish to discuss some validity issues associated with the research approach in the rest of this chapter and conclude with a validating framework adapted from Day and Bobeva (2005).

To validate the methodological approach in IS research, it is necessary to address the authenticity, plausibility, and criticality of the dataset (Walsham, 2006). These notions are discussed here based on the research methods presented earlier in this chapter. To confirm authenticity, I collected data from two different developing countries: Nepal and Indonesia. These countries frequently host severe disasters, including earthquakes, tsunamis, liquefication, landslides, and cyclones. Two rounds of the Delphi survey were conducted electronically (see the previous section) to minimize biases and achieve more authentic results (Dalkey, 1969). As unintended biases cannot be avoided in qualitative research (Darke et al., 1998), the current data collection and analysis may also have experienced this. For instance, the panelists may have given little time to realizing the importance of this study and answering the questionnaire thoughtfully. Additionally, while analyzing the data, I, both as a researcher and a human being, may not have been critical enough to explore in-depth messages from the data.

By publishing the findings and results in peer-reviewed journals and conference proceedings, this research confirmed its plausibility. According to Benbasat et al. (1987), research data can achieve richness and better accuracy if it is evaluated by multiple researchers. Their data interpretations and evaluations are more critical for supporting or contradicting the findings, thus allowing readers to benefit from the latest innovations or advancements and fulfilling the criticality requirement. Furthermore, to improve the accuracy, credibility, and validity of this study, I examined the interpretations of the evaluated decision factors and the newly identified factors with the panelists in the second survey round (Bygstad and Munkvold, 2010) and, later, with the research community at an IS conference.

Although the Delphi panel was not large, I found it reasonable to proceed further since the panelists' expertise in HL operations was more important than their number (Gossler et al., 2019). For conducting this research as an explorative study, having between five and 20 experts onboard seemed sufficient to form a Delphi panel (Grime and Wright, 2014; Richardson et al., 2016). Supportively, the review from Diamond et al. (2014) indicates that most previous Delphi studies (around 60%) have incorporated ten or fewer participants in the final survey round.

Unlike the traditional online surveying mode for Delphi studies (Richardson et al., 2016; Stewart et al., 2017), I preferred conducting it electronically (known as E-Delphi[31]) (Aljamal et al., 2016; Avery et al., 2005; McMillan et al. 2016). The extant literature recommends E-Delphi as a practical and effective surveying method. It supports more extensive questionnaire content, presented in a tabular format, much like Microsoft Word. Such features are unavailable in the

[31] Although *E-Delphi* is named here, it is not conceptualized in this dissertation.

online survey design platform. The panelists received regular reminder emails if they did not reply on time or if the deadline (or the extended deadline) was about to expire.

Instead of following the Delphi method's traditional starting process (e.g., open-ended questionnaire or brainstorming sessions), this study provided participants with a list of decision factors retrieved from the literature (Melnyk et al., 2009; Richardson et al., 2016). For better understanding and easy rating, decision factors for HRD–DM were presented descriptively in the questionnaires and divided into three categories: decision objectives, decision variables, and decision constraints. To avoid obtaining neutral answers, a six-point Likert Scale was employed for rating: *1 – most unimportant; 2 – unimportant; 3 – somewhat unimportant; 4 – somewhat important; 5 – important; and 6 – most important* (Stewart et al., 2017). The questionnaire also contained a consent form. The panelists were requested to complete and return it with their replies, and they received a non-disclosure agreement at the end of the questionnaire.

The Delphi technique allows several rounds of the survey to be completed until a convincing result is identified (Scheibe et al., 2002). To find such results and stop further surveying, researchers measure consensus, general agreement, or some other termination criteria (Heiko, 2012). However, although the measuring consensus is important, Heiko (2012) recommends not considering it as a stopping criterion for Delphi rounds because it would destroy the original surveying concept by awarding consensus to unstable topics. Thus, Dajani et al. (1979) suggest that issues must gain stability before consensus is measured. They propose hierarchical termination criteria for Delphi rounds, where consensus can only be measured if responses are consistent in multiple successive survey rounds. I incorporated both concepts for running the survey up to two rounds in this study.

In addition to ratings, the panelists were requested to explain their scores on each decision factor in plain text. However, this option was unpopular among the panelists, as they seldom replied to it, and, if replied, their answers carried the same meaning as their ratings. For example, rating a decision factor as *6* and explaining that the rating indicated the topic was *very important* meant the same thing. So, this explanation option did not affect the analysis. The open-ended information from the survey and the interviews produced, when synthesized, qualitative data to methodically present the entire HRD process effectively and efficiently (Varho and Tapio, 2013). Thus, a good alignment between the research objectives and methodologies was maintained to present the findings from the Delphi study.

Although this study initially targeted humanitarian responders from Indonesia and Nepal, the final panel encompassed global participants: from the US, Switzerland, Thailand, the Netherlands, Iceland, and Brazil (see Appendix E for panelists' profiles). Therefore, instead of just having an understanding from the Asian continent, the HRD decision factors were validated from intercontinental viewpoints. The panelists endorsed the decision factors based on their worldviews (as insider or outsider) about the event and their participation in responding to it (Clarke and Parris, 2019). Thus, a universal, shared understanding of the validated decision factors could be inferred for eliciting them as the core system requirements.

As the Delphi panel had a minimal number of participants from some of the represented countries, the cultural comparison and analysis were not considered in this research. However, the societal and cultural contexts of communities play a vital role in successful relief operations. Conducting surveys on a larger scale may generate better results. Two academics (one from Indonesia and one from Nepal) assisted me in handling linguistics issues for this project. However, the Indonesian experts who requested linguistics support ultimately decided not to participate, and, perhaps, for this reason, they remained irresponsive to my contact in the latter stages. Thus, they and their expert opinions on the topic were lost.

The ensure the accuracy and consistency of the research, four professors from the hosting university evaluated the validity and reliability of the Delphi questionnaires (Bolarinwa, 2015). These academics had long experience in constructing survey questionnaires in social science and IS fields. They theoretically validated the construction of the first questionnaire, which guided me to develop the second one (Bolarinwa, 2015). I consulted these experts about the contents of the questionnaire (how detailed or condensed), the survey presentation (easy going), and the research explanations (how extensive). After revising the initial version five times, the questionnaire was finalized to distribute among potential respondents. However, for practical validation, I inspected the panelists' reactions to the *unable* *to answer* option in the initial questionnaire. Their rare selection of that response practically validated the survey.

To test the survey's reliability, Cronbach's alpha (α) was calculated for the initial questionnaire using the formula from Allen and Yen (1979) presented in Equation 2.

$$Cronbach\ \alpha = \frac{n}{(n-1)}\left[1 - \frac{\sum Yi}{X}\right] \quad (2)$$

(*n=number of attributes; Y_i=items' variances; X=composite variance*)

Although the general acceptance of reliability is *α≥0.70* (Nunnally and Bernstein, 1994), the survey scored over 0.7 in all three categories of decision factors: α=0.814 for decision objectives, α=0.763 for decision variables, and α=0.873 for decision constraints. However, although I wished to evaluate a total of 35 decision factors and the operational ecosystem for HRD in a single questionnaire, a few panelists found the survey extensive and time-consuming. After getting an adequate explanation, they understood the difficulty of designing such a comprehensive questionnaire by keeping all the decision factors in the same place. Hence, I received no such complaints in the second round. Table 4.5 demonstrates the validation of the Delphi study.

Table 4.5: Validation of the Delphi study (adapted from Day and Bobeva [2005])

Criteria	**Description**
Confidence Levels	**Role of the researcher.** I solely conducted the study and did not participate in it. To be transparent, I explicitly described the purpose and procedures of retrieving decision factors to the panelists in the initial contacting emails.
	Subjective interpretation. Instead of just naming them in the questionnaires, I concisely described the carefully listed decision factors to avoid fluctuations in understanding. The panelists were free to criticize the listed factors, in addition to rating them, and were able to propose missing but essential decision-making factors. In the second survey, they had the opportunity to check the analysis report from the previous round and modify their scores if necessary.
	Self-assessment test. To avoid bias, I statistically analyzed the collected data (Hsu and Stanford, 2007; El-Gazzar, 2016). The general agreement for the decision factors was measured by calculating Kendall's W in the SPSS-nonparametric test.
	Reliability and validity of questionnaires. To measure the reliability of the initial questionnaire, I calculated Cronbach's alpha (α) (Allen and Yen,1979). The questionnaire was validated both theoretically by the academics and practically by counting the number of times the *unable to answer* option was selected.

Criteria	Description
	Psychological factors. As a facilitator of the survey and a researcher, I tried to minimize participants' psychological errors by providing clear instructions for answering the questionnaires, offering an open window for questions, extending flexibility on the deadline date and mode of participation (survey/interview), and providing interpreter(s) when necessary. However, some psychological issues were difficult to detect and, hence, could not be addressed, such as work pressures, survey completion time, language problems, permission from the affiliated organizations, or the moods of the informants (Day and Bobeva, 2005).
Rigor	**Internal validity.** Panelists' feedback on listed decision factors, as well as their recommended new decision factors, were carefully addressed. Changes and confirmations in ratings were acknowledged and reflected in the final ranking.
	Framework representing the ability of the questionnaires. To motivate the participants, I explicitly described the purpose and procedures of retrieving decision factors, the associated problem areas to HRD, and how decision-making in HRD is hampered by that of the other problem areas.
Credibility	**A form of triangulation.** The incorporated new decision factors, mostly suggested by interviewees, were evaluated by the survey panelists (having individual worldviews) as a means of triangulation—scrutinizing the existence or acceptance of these factors in different geographical locations.
	The contextual setting of individuals. The panel encompassed members from eight countries with extensive working experience in many natural disasters. Depending on their contextual settings, variations in answering patterns could be attributed to their domain backgrounds, job titles, and ethnicities. However, before commencing the survey, I made sure that each participant clearly understood the study's aim.
	The general applicability of the result. Although this study produced a summarized list of essential decision factors based on the Delphi results, the complete generalizability of those decision factors in various contexts is either impossible or very limited. Instead, this study provides a debatable list of prioritized (consensus-based) decision factors, guiding decision-makers to quickly identify (or select) potential decision variables to achieve specific objectives by tackling particular decision constraints.

4.4 Chapter Summary

This chapter articulated the research design for this study. It described its philosophical world view, along with the strategies of inquiry and research methods. It revealed that HL researchers should take the pragmatic approach for finding working solutions to the domain's practical problems. Instead of employing quantitative (e.g., survey, literature review) and qualitative (e.g., interviews, field trip and observation) strategies individually, researchers should blend them for getting a better result in data collection and analysis. By validating the study's research methods, this chapter demonstrated the suitability of the Delphi technique in conducting IS research for building a DSS in the HL domain.

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5 Research Publications

This chapter summarizes the findings and contributions from the five papers that form the basis of this dissertation. Each paper addresses specific RQs to achieve its aims and report related findings. The subsequent sections briefly discuss them. This chapter concludes with a presentation of the overall story of this dissertation, where the connection between the papers and their contributions to this project are illustrated. Table 5.1 overviews the five published papers, and the full papers are included in Appendix G. They are ordered according to their relevance to the dissertation, not by their publishing years.

Table 5.1: Overview of the published papers related to this research

ID & Year		Paper Detail
Paper 1 2017	**Title:**	Understanding decision support in large-scale disasters: challenges in humanitarian logistics distribution
	Authors:	Mohammad Tafiqur Rahman, Tina Comes, and Tim A. Majchrzak
	RQ:	What are the challenges for an operational DSS to support distribution planning?
	Outlet:	International Conference on Information Systems for Crisis Response and Management in Mediterranean Countries (ISCRAM-med)
Paper 2 2019	**Title:**	Deep uncertainty in humanitarian logistics: decision-making challenges in responding to large-scale natural disasters
	Authors:	Mohammad Tafiqur Rahman, Tim A. Majchrzak, and Tina Comes
	RQ:	What are the available approaches for handling DU and how would they be applicable to HRD in large-scale natural disasters?
	Outlet:	International Journal of Emergency Management (IJEM)
Paper 3 2018	**Title:**	Pragmatism in decision support system research: the context of humanitarian relief distribution.
	Author:	Mohammad Tafiqur Rahman
	RQs:	Which paradigm is suitable for guiding DSS research in HL to solve decision-making problems in the HRD process? Why and how is it suitable?
	Outlet:	International Journal of Information Systems for Crisis Response and Management (IJISCRAM)
Paper 4 (Submitted) 2020	**Title:**	A conceptual framework to support decision-making in humanitarian relief operations
	Authors:	Mohammad Tafiqur Rahman, Tim A. Majchrzak, Tina Comes, and Maung K. Sein
	RQ:	How does decision-making in other problem areas influence decisions in HRD?
	Outlet:	An international peer-reviewed humanitarian journal
Paper 5 2020	**Title:**	Requirements for RD decision-making in humanitarian logistics.
	Authors:	Mohammad Tafiqur Rahman and Tim A. Majchrzak
	RQ:	What decision factors do experts prefer for effective HRD–DM?
	Outlet:	Lecture Notes in Information Systems and Organisation (LNISO)

5.1 Paper 1 - Identifying Research Challenges

Rahman, M. T., Comes, T., & Majchrzak, T. A. (2017). Understanding Decision Support in Large-scale Disasters: Challenges in Humanitarian Logistics Distribution. In Dokas, M.I., Saoud, N.B., Dugdale, J., & Diaz, P. (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response And Management in Mediterranean Countries* (pp. 106-121), Xanthi, Cham: Springer.

DOI:10.1007/978-3-319-67633-3_9

Summary: The first paper establishes the foundation of this IS research in the HL domain. To save more lives, timely humanitarian assistance is crucial, and this is impossible without proper and practical support in HRD–DM (Rolland et al., 2010). In current practice, HDMs exploit experience-based deployment of HL operations, which can cause delayed decision-making and unsatisfactory results in such crucial situations (Darcy et al., 2013). Therefore, to provide decision-makers with an IS-based DSS, this paper investigates the challenges IS researchers may face when eliciting requirements for, designing, and developing the DSS system for HRD–DM.

Findings: This paper identifies three significant challenges for developing IS to support decision-making in HRD: rapid HL modeling, decision analysis for operational research, and DU. The paper also establishes relationships between these challenges and argues that IS researchers should address them to assist decision-making in humanitarian operations, especially in HRD. Hence, the relevant DSS system can only be achieved by considering these unavoidable challenges and following the guidelines suggested in the rest of the papers (where these challenges are addressed).

5.2 Paper 2 - Deep Uncertainty Conceptualization

Rahman, M.T., Majchrzak, T.A. and Comes, T. (2019). Deep uncertainty in humanitarian logistics operations: decision-making challenges in responding to large-scale natural disasters. *International Journal of Emergency Management*, *15*(3), pp.276–297.

DOI: 10.1504/IJEM.2019.10023857

Summary: The second paper studies the characterization of DU in HL. When responding to large-scale natural disasters, HDMs struggle to identify proper situational assessment information in the affected areas (Comes et al., 2013). Thus, demands constantly fluctuate, and there are irregularities in supplying and delivering relief goods (Gralla et al., 2015). To meet such dynamic relief demands, decision-makers exploit various context-dependent decision-making models or tools, which result in numerous, unmapped decision factors (Rahman et al., 2017). Unlike other research fields, addressing DU in HL is quite challenging and complicated (Altay and Green, 2006). Decision-makers cannot wait for a longer time for better iterative results, nor can they process supply and demand in businesslike, structured ways. Hence, this paper first conceptualizes the notion of DU and then examines its applicability in HL, especially in HRD–DM.

Findings: This paper reports that DU is a relatively new topic for HL research. The few HL researchers who have discussed DU in their studies have done so at an abstract level. After a detailed investigation, this paper reveals 13 approaches to DU and, based on their characteristics, categorizes them into three groups: traditional, adaptive,[32] and robust.[33] A detailed discussion is presented in the paper, not only to identify the influences and dependencies among the groups, but also to understand their working procedures. Although traditional approaches are partially suitable, this study argues for a collaborative contribution between adaptive and robust methods to solve HL problems. Hence, it recommends a *modified Adaptive Robust Design (mARD)* approach to address DU in HL. While suggesting that multiple scenarios be covered in iterative ways, the paper emphasizes evaluating the essential and specific decision factors for different problem areas (addressed in Paper 4) associated with HRD–DM. It finally recommends incorporating seven notions into the process: (i) being bounded by time, (ii) being bounded by an accepted threshold of iteration, (iii) incorporating data transformation, (iv) handling unidirectional process failure, (v) maintaining information quality, (vi) addressing critical assumptions (decision factors), and (vii) conceptualizing DU and its consequences during humanitarian operations. Such conceptualizations are discussed in Section 5 in Paper 2.

[32] Adaptive: Coping with new situations (see Rahman et al., 2019 for detail).
[33] Robust: Perform well in all conditions (see Rahman et al., 2019 for detail).

5.3 Paper 3 - Research Philosophy

Rahman, M.T. (2018). Pragmatism in Decision Support System Research: The Context of Humanitarian Relief Distribution. *International Journal of Information Systems for Crisis Response and Management*, *10*(3), pp.63-83.

DOI: 10.4018/IJISCRAM.2018070104

Summary: The third paper examines the philosophical underpinnings of this research. Since the humanitarian response to natural disasters is a real-world problem, HDMs demand support systems that will be practically implementable in dynamic situations and DU. To offer this, researchers need a better paradigmatic understanding of the research domain, identifying the ontological, epistemological, methodological, and axiological foundations of each research problem. This understanding would guide them to answer constructive research queries, identify appropriate data collecting sources and methods, and conduct value-adding research (Dobson, 2001; Wade and Hulland, 2004). Hence, this paper first conceptualizes the philosophical understanding of IS research and then examines the applicability of each paradigm in HL to solve HRD–DM problems regarding large-scale natural disasters.

Findings: This paper reports the philosophical foundation of this research. To underpin its findings, the paper deeply examines four components (ontology, epistemology, methodology, and axiology) of four philosophical paradigms (positivism, interpretivism, critical realism, and pragmatism). Based on an extensive investigation, it not only identifies pragmatism as a suitable paradigm for HL research (especially in HRD–DM) but also explains why other paradigms are not ideal for such research. While graphically presenting the contribution of pragmatism in HL, the study also reports the philosophical, practical, and technical challenges of using this approach. However, my investigation reveals the existence of (extensive) pragmatic practice in the field, but this is limited to academic research. This point requires further investigation and more detailed discussion.

5.4 Paper 4 - Empirical Foundation

Rahman, M.T., Majchrzak, T.A., Comes, T., and Sein, M.K. (submitted 2020). A conceptual framework to support decision-making in humanitarian relief operations.

Under review in an international peer-reviewed humanitarian journal.

Summary: The fourth paper establishes the empirical foundation of this research by rigorously and systematically reviewing HL literature on decision-making. From a review of 138 (out of 1,307) academic articles, I shortlisted and investigated 30 mathematical decision-making models practically implemented in different humanitarian disasters. The study provides an understanding of achieving the intended decision objectives by using specific decision variables and constraints on the focused problems. This paper also covers framing the encountered problem areas in the HSC, along with their respective decision factors and interconnectedness. Based on the findings, this paper develops a holistic conceptual framework and frames HL as an ecological system.

Findings: This paper argues that the number of decision-making factors increases because of unstable operational environments, where dynamic relief demand, incomplete or contradictory situational information, distinct opinions from involved stakeholders, and higher economic burdens exist. As these problem areas are mostly studied individually in the existing HL literature, the research domain lacks a holistic view of the overall HRD. To address the gap, after the extensive and systematic review, this study identifies six problem areas that encompass a total of 14 decision objectives, 28 decision variables, and 21 decision constraints (see Paper 4 for detail). By sharing decision factors, the problem areas show interconnectedness, which this paper quantifies and presents as a conceptual framework, framed as an ecological system. For a successful humanitarian relief operation, it emphasizes having a joint and concurrent approach by balancing decision factors among the affected problem areas, so each of them can achieve its intended operational objectives.

5.5 Paper 5 - A Delphi Study

Rahman, M.T., and Majchrzak, T.A. (2020). Requirements for Relief Distribution Decision Support in Humanitarian Logistics. In: A. Siarheyeva et al. (eds.), *Advances in Information Systems Development. ISD 2019. Lecture Notes in Information Systems and Organisation, 39,* (pp. 93-112), Springer, Cham.

DOI: 10.1007/978-3-030-49644-9_6

Summary: The fifth paper reports the empirical study of this research and is built on the framework developed in Paper 4. A Delphi study was chosen as the appropriate approach for the research purpose. The study involved a panel of 23 worldwide HL experts from academia, governments, and national and international non-governmental organizations (NGOs). The panelists evaluated and ranked the decision factors identified from both the literature and the field in two consecutive rounds. The findings represent a strong consensus among the participants. All communication with the experts and all questionnaire dissemination took place via e-mail.

Findings: The findings of this paper are mainly twofold. First, the paper provides two comprehensive sets of practically feasible decision factors individually rated by the experts. Over 70% of the panelists recognized the necessity of the listed factors for deciding HRD. By using different statistical tools, the decision factors were prioritized, and, based on this prioritization, they were further clustered into three categories: high, mediocre, and least affecting factors. Decision-makers, now, can have a better understanding of the importance of the desired factors individually or as a group. However, since the combined list of decision factors (from academia and practice) became larger and would be impractical to manage, this paper provides HDMs with a comprehensive list of top-ranked decision factors. It can assist them in quickly identifying crucial decision factors for (overall) faster HRD–DM. Second, a correlation matrix is presented in this study to help decision-makers understand how different decision variables and constraints influence the achievement of each decision objective. While analyzing the relationships, I noticed the double role (positive and negative) of some decision factors in the process. Hence, decision-makers are encouraged to use those dual-role-playing factors carefully to achieve the desired operational objectives. However, based on experts' recommendations, this paper claims that societal support from nearby communities should be incorporated for faster response in the early hours of disasters; it also emphasizes meeting survivors' needs with quality relief goods rather than a large quantity.

5.6 The Overall Story of the Dissertation

Taken together, the five papers have developed the overall research story conveyed by this dissertation. Figure 5.1 illustrates how the papers were built on each other to achieve the desired research goal. The figure is subsequently explained by discussing how individual papers contributed to addressing the RQs and accomplishing this dissertation. This section, as well as this chapter, concludes by precisely summarizing the contributions from the published articles.

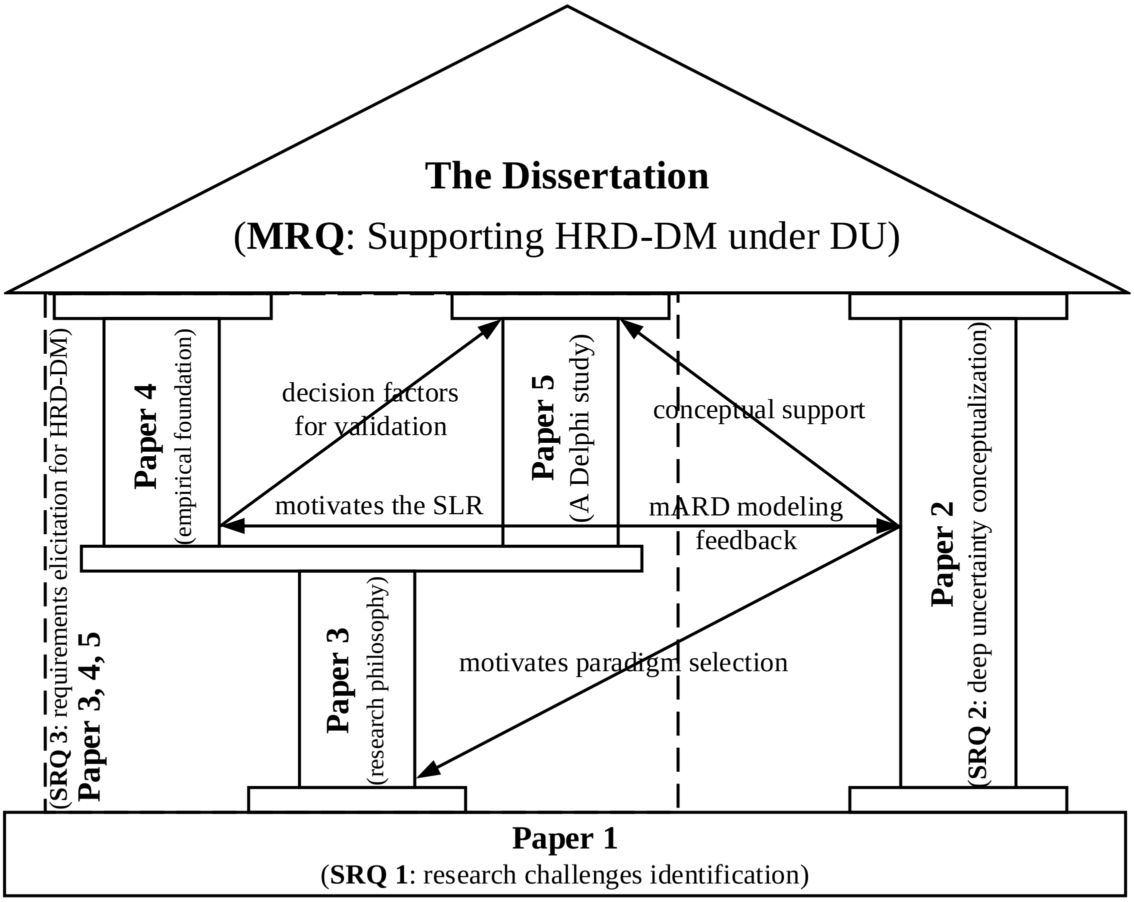

Figure 5.1: Contribution of the publications to this dissertation

Each paper contributed to this dissertation in specific ways. By understanding the problem from a broader perspective, Paper 1 identifies three significant research challenges for supporting HRD–DM. These challenges are addressed by the rest of the research papers (2–5) to model the proposed humanitarian DSS. Hence, Paper 1 was considered the foundation builder of this research. Paper 2 studies the characteristics of DU in HL operations to support the DSS model with decision alternatives. It, therefore, motivated the selection of the philosophical paradigm (Paper 3) for this research and the SLR process (Paper 4) by aiding literature selection. It also supported data validation (Paper 5) by conceptualizing DU in the process. The papers also concentrate on finding research methods (Paper 3), eliciting system requirements (Paper 4), and ensuring validation (Paper 5). Paper 3 examines the philosophical underpinnings of HL problems to determine the appropriate method for designing the DSS system. It suggests mixing qualitative and quantitative methods for data collection, evaluation, and analysis, which were adopted in the remaining two articles. Paper 4 examines the HSC model—how it works, what problem areas it encompasses, and how decisions in those problem areas affect the overall HRD. At the same time, Paper 4 also studies the existing decision-making models to collect necessary decision factors associated with the identified problem areas. The accumulated findings from this article were translated as requirements for the envisioned DSS system. These decision requirements were then empirically validated by the panel of HL experts, and Paper 5 articulates them.

Table 5.2 demonstrates the contributions made by the published research articles to this dissertation.

Table 5.2: Contributions of the published papers to the dissertation

ID	Contributions to the dissertation
Paper 1	This paper identifies and discusses critical issues for IS research in the HL domain and establishes the foundation for this research. Addressing those challenges (rapid HL modeling, decision analysis for operational research, and approaching DU) in the rest of the papers (2–5) led the project further towards designing a DSS for faster HRD–DM. To guide the overall research, this paper proposes a process model, which can be extended to operational DSS development.
Paper 2	This paper visualizes and discusses HL problems through the DU lenses. By incorporating available techniques for addressing DU, this paper generates a conceptualization, which can be referred to in other research disciplines as well. It recommends an *mARD* approach to DU in HRD–DM. The findings and the model support other contributions (such as paradigm selection, SLR conduction), as well as the final system model.
Paper 3	This paper studies and frames the philosophical underpinnings of IS and DSS research in HL. After an elaborate paradigmatic discussion, it recommends pragmatism as the paradigm for HL research and, thus, contributes to identifying a suitable method for the empirical study. To guide the overall research, this paper proposes a model that shows how decisions can be made pragmatically for HRD. Besides humanitarian contexts, the discussion presented in this paper can assist researchers from other disciplines in understanding the philosophical foundations of their work.

ID	Contributions to the dissertation
Paper 4	This paper establishes the empirical foundation of this project by discussing the landscape of HL in this research and reporting a rigorous SLR. It identifies the crucial decision factors and their associated problem areas in HL. For effective decision-making in HRD, this paper recommends concurrent activities between problem areas and proposes a conceptual framework, which quantifies the interconnectedness between these areas.
Paper 5	This paper summarizes this research's empirical study and findings. Through a Delphi study, it investigates the literature-based decision factors identified in Paper 4, incorporates a few new factors from practice, and, finally, evaluates and prioritizes these factors to provide decision-makers with manageable and comprehensive advice. By using the understandings from the literature and practice, this paper proposes an HRD process model, which accelerated the ultimate system design.

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6 Research Findings

This dissertation highlights IS research concerning operational decision-making support in HL under DU. By systematically identifying the decision requirements and empirically validating them, I addressed the call for a process approach to designing a DSS for HRD. This chapter discusses the findings by answering the RQs (delineated in Chapter 1). Although the MRQ is presented in the initial section (6.1), it is answered in the final section (6.5) by proposing some actions required during relief deployment. Sections 6.2, 6.3, and 6.4 present how the MRQ was answered and, in doing so, establish the basis for modeling the humanitarian DSS. Figure 6.1 shows the main findings of this study and how they contribute to system modeling. The figure is based on Benyon's (2019) four key steps to designing IS (envisionment, understanding, evaluation, and design); these are applied in the figure to structure the research process in an organized way. Although such designing principles allow IS designers to start their activities with any preferred step, they must follow the presented order for studies similar to this research.

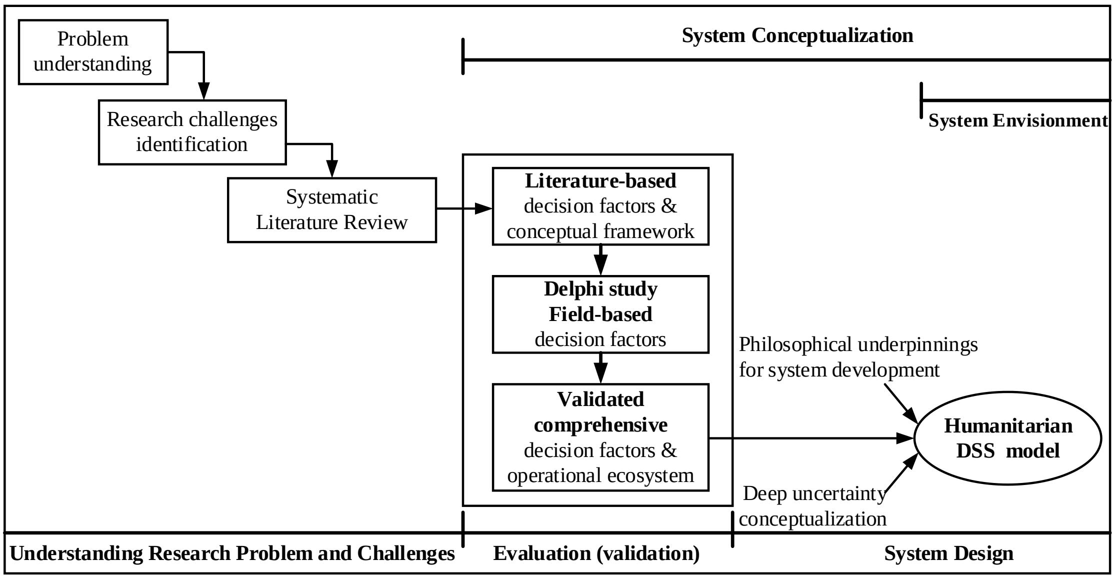


Figure 6.1: IS research steps for modeling the planned humanitarian DSS

6.1 Decision Support System Design

MRQ: How can decisions in HRD be supported under DU?

To answer this research question, I envisioned developing an IS supported DSS model for HRD–DM under DU. By leveraging an adaptive and robust approach to decision-making, the system should offer decision-makers pragmatically generated decision alternatives. After discussing those alternatives with decision-makers from other associated problem areas, relief distribution decision-makers can select the most effective implementation idea.

The MRQ has further been divided into three SRQs. The first SRQ studies the breadth and the state of the field to understand the challenges related to IS research in the HL domain in Section 6.2. Later, in Section 6.3, the second SRQ inspects the applicability of DU in HL. Then, the third SRQ, in Section 6.4, discusses decision requirements elicitation for supporting HRD–DM. Finally, the answers from these three SRQs are combined to present the DSS design in Section 6.5.

6.2 Research Challenges Identification

SRQ 1: What are the significant research challenges for operational decision-making in HL?

The overall findings of SRQ 1 revealed three salient challenges for DSS research in HL: rapid HL modeling, decision analysis for functional responses, and addressing DU. Understanding and addressing these challenges established the research foundation to model the aimed humanitarian DSS for supporting HRD–DM. Although these challenges have been introduced in Chapter 5 and elaborated in Paper 1, here I reiterate their relevance to this study type. This section concludes with a brief discussion of the necessity of multidisciplinary research in this genre.

Decision-making in the HSC's downstream operations is critical and challenging. Here, HDMs must be involved in all processes to distribute relief goods to affected people: retrieving the delivered relief goods at entry points, warehousing and managing them in suitable locations, creating schedules and transporting them to the demand points, and, most importantly, distributing them among beneficiaries through a proper relief supply chain. Although such a relief drive requires concurrent activities among these problem areas, the literature analysis has reported individual value-achieving without knowledge of the problem areas and the extent of their involvement in decision-making. Decision-making in HL is traditionally supported by different mathematical models for achieving various decision objectives by optimizing multiple decision variables and constraints. So, researchers, clustered into different problem areas, concentrate only on achieving area-specific decision objectives, rather than working together in an integrated manner. With few notable exceptions, a holistic understanding of the overall process of decision-making is seldom addressed, which hampers HL modeling for rapid operations (the first challenge).

To address the second challenge, this research understood decision analysis for operational responses as examining the existing decision-making models in the literature, as well as identifying and evaluating crucial decision factors and associated problem areas incorporated in relief operations. Without such understandings, recommending and implementing HRD–DM support is extremely difficult or sometimes impossible. Hence, the traditional conceptualization of decision analysis in HL is insufficient; a joint venture of humans and technologies is necessary. Software-system-supported decision analysis can help to produce implementable decision alternatives to fulfill various aspects of the operational environment. To support requirement analysis for such software systems, this IS research delved deeply into literature and practice to identify decision factors and relevant problem areas and map them to reveal their interconnectedness. This finding helped system modeling, which, in combination, can fulfill system requirements to generate decision alternatives and support decision-makers in finding the best matches.

The third challenge is incorporated in understanding DU in HRD–DM. Decision-making in HL is not the same as in traditional business logistics problems. It always experiences challenges with dynamic supplies and demands due to incomplete, or even contradicting, contextual information, which often changes constantly; distinct (i.e., personal) opinions from stakeholders; severe economic restrictions; and the interconnectedness of decision problems. Different decision-makers interpret a single incident differently to achieve different contextual objectives. Thus, conceptualizing DU in requirement analysis will facilitate producing decision alternatives to assist with operational decision-making. Since this notion is new to HL, I studied it separately and elaborately by defining the next SRQ.

Besides the abovementioned conceptualizations, HL researchers require multidisciplinary understandings of the issues they face since problems in this discipline are not standalone or isolated. They also require assistance from researchers in other fields. This research has revealed that, for prototyping and building a computer-aided humanitarian DSS, knowledge from computer science, decision science, business, management and accounting, engineering, and mathematics is essential. The process also requires significant support from IS research for understanding the societal aspects (working procedures and interconnectedness within different problem areas) of the decision problems and their potential solutions. Such conceptualization will help researchers not only in eliciting requirements for system modeling, but also in recommending collaborative research disciplines for system development. Figure 6.2 shows the multidisciplinary spectrum for the reviewed samples in decision objectives and decision constraints categories (see Chapter 3 for the categorization).

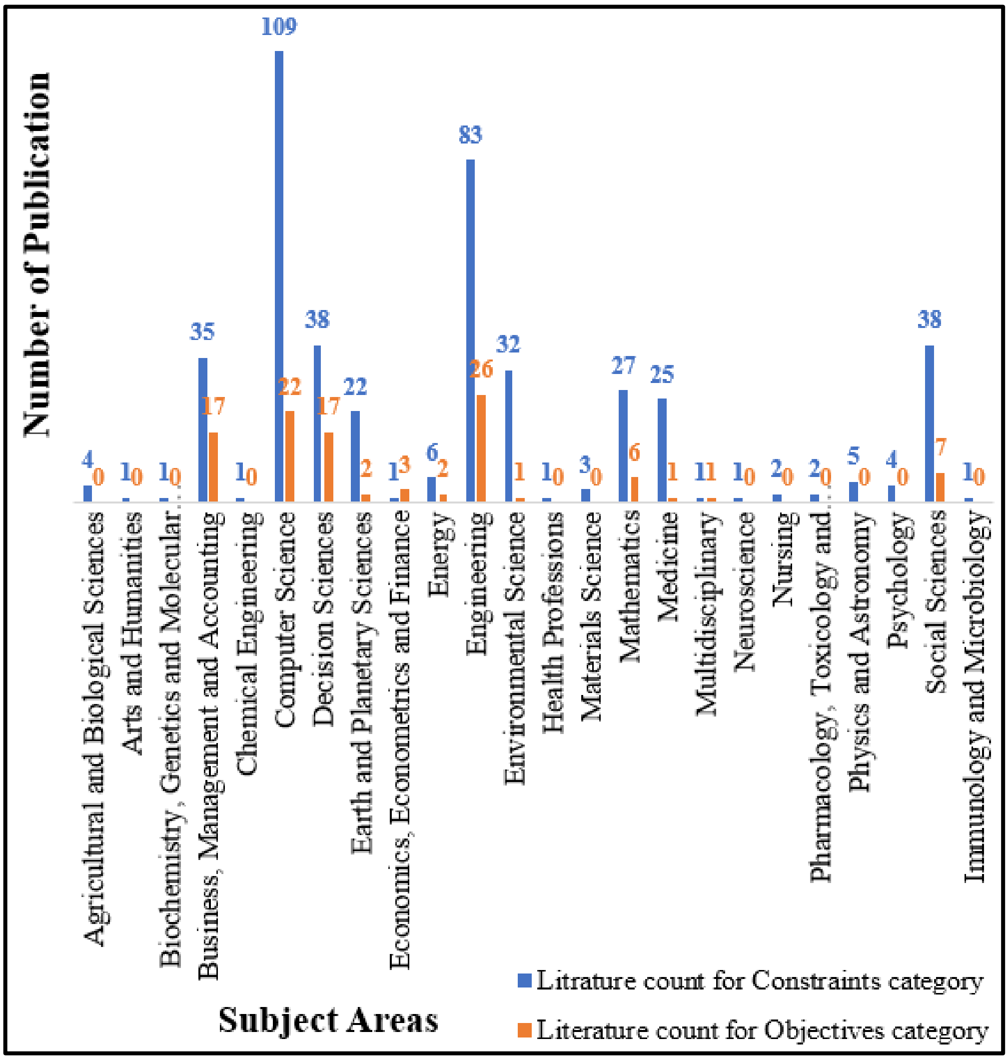


Figure 6.2: Number of articles per research discipline in both categories

6.3 Deep Uncertainty Characterization

SRQ 2: How can DU be characterized in HL for HRD–DM?

The findings from SRQ 2 are reported and discussed in Paper 2 and summarized in Chapter 5. The concept of DU in HL was also introduced in the previous subsection. Here, I wish to discuss its characterization in HL operations and research.

Unlike regular academic research, DU is characterized in HL, not only by information inadequacies for framing the upcoming future, but also by data formatting. Since HDMs receive disaster data of all formats (structured, semi-structured, unstructured, qualitative, and quantitative), it is even more crucial to adequately process them to produce enough relevant information to determine the next relief deployment. Too much irrelevant, or too little relevant, information is impractical for humanitarian decision-making. In addition, researchers' pragmatic limitations for analyzing and understanding complex operational systems exacerbate decision-making challenges. On the other hand, the HRD process encompasses multiple problem areas, in which the same operational context can be interpreted differently by area-specific decision-makers. This opinion diversity affects the entire HRD network and makes its successful operations vulnerable.

Identifying appropriate problem-solving models, along with their necessary parameters and alternative outcomes, creates similar uncertainties in practice. In HL's field of operations, many non-coordinated responding groups activate numerous decision-making alternatives with customized structures and new, unmapped decision factors. These alternatives cannot be adequately weighted or valued since their outcomes lack consensus on mandates and objectives of humanitarian response and, thus, their procedural impacts (positive/negative) cannot be convincingly determined. So, decision-making in such circumstances is mostly based on decision-makers' experiences from previous, context-variant endeavors, which sometimes make the overall HRD delayed and cumbersome.

Furthermore, having a surplus of inventory from previous deployments at an HRD center and lacking goods in a current deployment are common scenarios in almost every HL deployment. It is more costly, in terms of economics and management, to return the leftovers to the points of origin or wait for the scarce goods to begin the operation. However, if the distribution network fails before completing the deployment, it becomes impossible to backtrack; the HRD network is operated in a one-way direction towards the points of distribution (see Paper 5). Therefore, researchers should support decision-makers in identifying potential adaptive and robust tactics for deploying humanitarian relief operations. In Paper 2, I propose an *mARD* approach to address DU in HRD–DM by restricting processing time and iterations. However, such restrictions are still a matter of discussion.

6.4 Requirements Elicitation for HRD–DM

SRQ 3: What are the requirements for supporting HRD–DM?

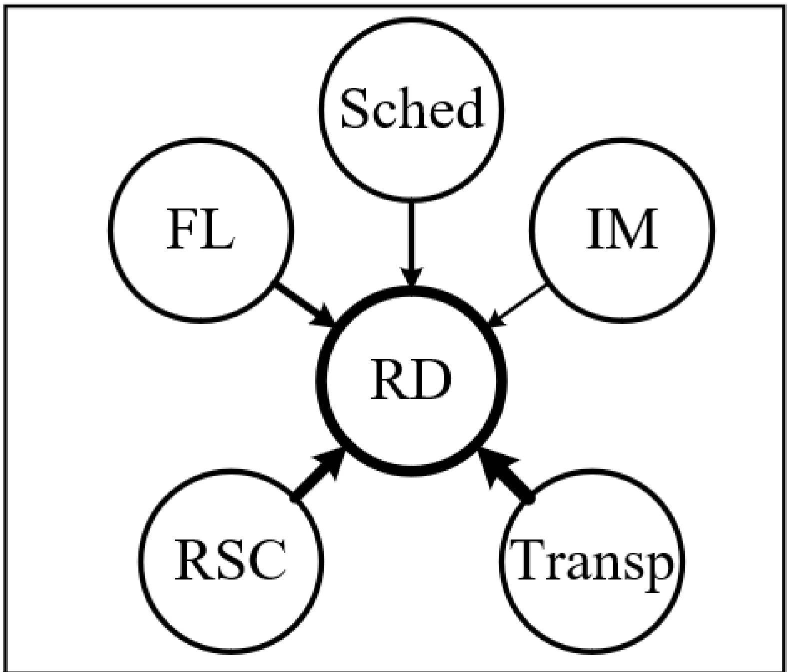
The HL research literature encompasses numerous optimization (mostly mathematical) models, which are highly contextual and problem-centric. These models rarely concentrate on studying other accompanying problem areas and correlated decision factors. Researchers emphasize solving area-specific problems without analyzing or understanding the effects of the solutions on other problem areas. Thus, the problem-solving techniques become unsustainable after serving the targeted, area-specific issues, and they are never used for other cases in similar domains. Therefore, Paper 4 studies the available DSS models in HL to elicit requirements for modeling the proposed humanitarian DSS. These requirements are validated in Paper 5, and Paper 3 identifies appropriate research methods for conveying this study. The remainder of this section briefly discusses the findings and validation of the decision factors but elaborates on the validation of the conceptual framework for HRD–DM. When combined, these results, along with the correlations between decision factors, answer SRQ 3 by defining them as the requirements for modeling and building the aimed operational humanitarian DSS.

To establish the empirical foundation of the research, Paper 4 rigorously and systematically reviews state-of-the-art HL literature. Thirty decision-making models are studied in detail to identify problem areas and their associated decision factors in humanitarian operations. This scrutiny reveals a total of 63 decision factors (categorized into decision objectives, variables, and constraints) across six problem areas (HRD, RSC, FL, IM, Transp, and Sched). After framing them, I observed that the elicited decision factors were not problem-specific at all times. On the contrary, the problem areas share some common decision factors. This commonality was conceptualized, assessed, and quantified to understand how decisions in each problem area affect decision-making in HRD. This interconnectedness between HRD and other problem areas was captured in a conceptual framework to enhance the understanding of operational concurrency in HL. Although all findings are reported in Paper 4, identified problem areas and their decision factors are shown in Appendix D.

Paper 5 empirically tests 35 decision factors (out of 63), which were identified for HRD in Paper 4. A two-round Delphi study was conducted to achieve this validation. In the first round, 23 HL experts assessed the provided list of decision factors by rating them (on a six-point Likert scale), and they recommended new factors that were missing. In the second round, the panelists received the analytical results from the previous round, as well as the list of 26 newly added decision factors for further validation. Results from both rounds were statistically analyzed to produce a manageable list of 22 (out of 61) decision factors. These were further prioritized based on the votes from the panelists. The complete validation is reported in Paper 5, and the final list is articulated in Table 4.3.

After analyzing the panelists' opinions on the literature-based operational conceptual framework demonstrated in Paper 4, I identified significant differences in the interconnecting prioritizations. The literature reports that *FL* is the most influential problem area for HRD–DM, while the panelists prioritized solving *Transp* problems for effective responses (Table 4.4). According to the panelists, the issues with *FL* have the least effect in HRD because these can be handled by getting support with mobile warehouses, redirecting fleets to nearby places, etc., but the operation becomes worthless if the relief goods, in whatever quantity, cannot be transported to the survivors. HRD requires active and secure distribution networks, conducted by drivers in technology-supported vehicles (of different types and capacities). These issues become crucial in the disaster environment. Since HL researchers, in most cases, concentrate on proposing problem-area-oriented optimization models, they lack a holistic understanding of the entire process. Therefore, although I found it sensible to consider the evaluated framework in the ultimate system design, I recommend in-depth future research on this issue.

The final conceptual framework can be considered as an operational ecosystem for distributing relief goods. It will assist decision-makers in learning how other problem areas are coevolving with HRD to make an effective HL operation. It will also inform them of the disruption of such activity, if any keystone problem areas fall apart. By studying the ecosystem, decision-makers can allocate resources according to the three decision-making levels: strategic, tactical, and operational. Therefore, researchers in HL should jointly explore these problem areas to support concurrent decision activities for gaining cumulative benefits. The final ecosystem is presented in Figure 6.3, where the weights of interconnectedness between *HRD* and other problem areas reflect the findings discussed in Section 4.3.2. To make this figure conveniently accessible, the interconnectedness quantifying matrix (based on experts' preferences) is reproduced immediately after the ecosystem. The thickness of connecting arrows reflects the effect of each problem area in HRD–DM.



Other Problem Areas	Experts' Preferences	
	Quantified Influences	Rank
Transportation (Transp)	O(7)+V(11)+C(9) = 27	1
Relief Supply Chain (RSC)	O(5)+V(9)+C(8) = 22	2
Facility Locations (FL)	O(5)+V(8)+C(4) = 17	3
Scheduling (Sched)	O(6)+V(8)+C(2) = 16	4
Inventory Management (IM)	O(4)+V(4)+C(7) = 15	5
Abbreviations: O: decision objectives; V: decision variables; C: decision constraints		

Figure 6.3: An operational ecosystem for HRD

To understand the relationships between HRD's decision factors, a correlational study is conducted in Paper 5. By consulting the proposed correlational matrix, decision-makers can quickly identify appropriate decision variables and constraints for achieving specific operational objectives. It is important to point out here that some decision factors show the special characteristic of being incorporated in every category (decision objective, variable, and/or constraint). By contrast, some others show both positive and negative correlations for achieving specific decision objectives. These issues are avenues for future research.

Finally, when accumulated, the validated decision factors for HRD, findings from the correlational matrix, and the validated ecosystem can serve as system requirements for prototyping and developing the system to support HRD–DM. HDMs can now quickly identify crucial decision factors and maintain a (prioritized) communication channel (with decision-makers in other problem areas) for faster decision-making in HRD. The proposed ecosystem should support them in recognizing which decision-maker to prioritize (and how much) for initiating humanitarian responses and completing them by achieving desired operational objectives, settled through negotiations between participating parties.

6.5 Answering the MRQ

To answer the main research question and build the model, I adapted the DSS system modeling concepts from Wallace and De Balogh (1985) and Watson (2018). These models are respectively demonstrated in Figure 1.3 and Figure 2.3. Based on the conceptualization of IS artifact modeling discussed in Chapter 2, here I propose the planned humanitarian DSS model to support HRD–DM under DU. This model covers the information artifact and social artifact facets, while keeping the technology artifact out of focus. The information portion is elaborately presented here, while the social elements are discussed in Chapter 7. The proposed humanitarian DSS model consists of four crucial components (data stores [DS], data analysis capability [DAC], normative models [NM], and data display and use [DDU]) as well as three management systems (database, model-based, and dialog). I discuss these components (Figures 6.4–6.7) and management systems first and then present and explain the overall design (Figure 6.8). This section ends with a functional model (Figure 6.9) for the new humanitarian DSS portraited in the previous figure.

Data stores contain information about the overall situation of a disaster and updated details on responding capabilities. It receives continuous field data through different channels connected with the responding environment—volunteers, stakeholders, decision-makers, researchers working in the situations, and possibly dedicated advanced technologies (e.g., artificial intelligence [AI] devices, Internet of

Things [IoT] devices, mobile devices). The data related to social capital[34] are continuously assembled to support data analysis for effective decision-making. DS supports needs-assessment and humanitarian responses to DAC by providing necessary information about previous solutions, decision factors, available resources, suppliers, the disaster environment, contexts, field conditions, demand, time, social capital, etc. By using acquired problem-solving knowledge, experts can create essential decision-making rules or update them accordingly.

After determining a relief deployment plan, decision-makers, through DDU, update the DS with appropriate operational information (e.g., exploited solution alternatives, resources used, participation, and potential suppliers). The information about newly identified decision factors, generated model alternatives in NMs, and selected alternatives is stored in the DS for later use. Through DDU, decision-makers may access the DSs to retrieve necessary data in the desired format and deploy HRD in the field. Decision-makers from other problem areas may also be granted access to the DS to achieve situational updates supporting the deployment. Since the DS will be receiving continuous disaster data of different types from various sources, cloud-based solutions can be implemented. The conceptualization of this DSS component is articulated in Figure 6.4.

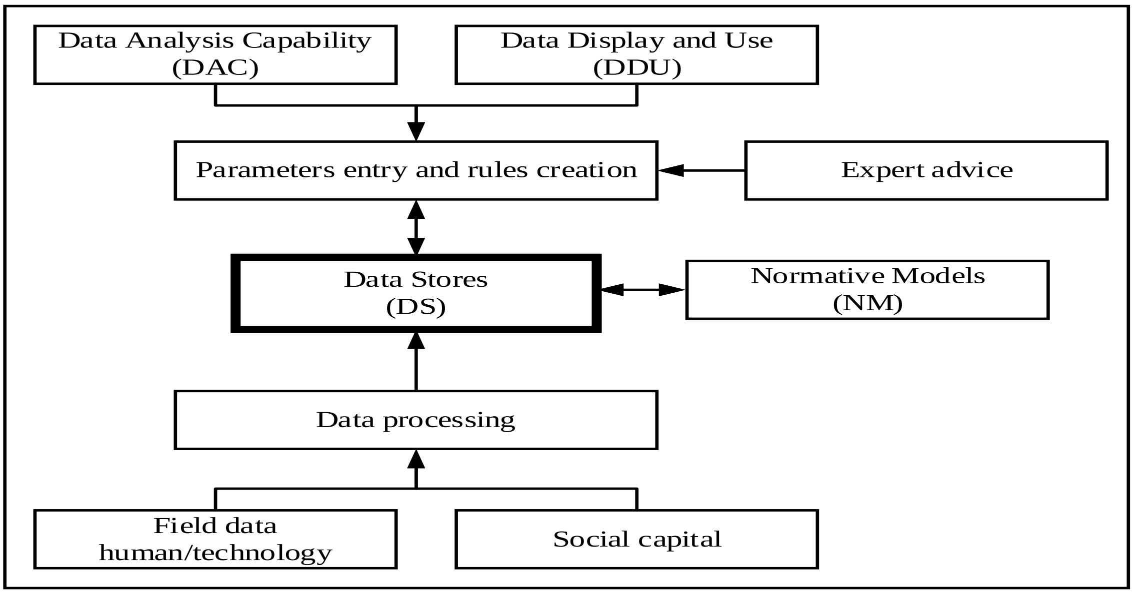


Figure 6.4: The conceptualization of the *data stores* phase

[34] The supports provided by neighbors immediately after the disaster onset and/or during relief drives.

Data analysis capability analyzes requirements for appropriate decision-making (such as decision factors and their correlations), participating problem areas, and their priorities and interconnections. This phase begins when decision-makers start processing continuous demand calls received from the field of operation. After receiving demand notifications through DDU, it initially analyzes and assesses the data to identify necessary decision factors, consulting either the extended version or the shortened, prioritized version of the identified decision factors. In essence, the achievement objectives are determined, along with associated and correlated decision variables and constraints. DS support this initiative with essential data for such assessments.

Decision-makers, in this phase, address and process continuous (up to an accepted threshold) demand calls, analyze and compare those with the existing set of decision factors, and update the dataset in the database (if necessary). By understanding (through consultation with the validated operational ecosystem) the achievement objectives and essential variables and constraints (along with contextual ones), they begin prioritizing contacting decision-makers in other problem areas to consult, negotiate, and deploy HRD. Through such discussions, related uncertainties are identified and fed to the scenario generation phase in the NM. Thus, decision-making activities can operate in pragmatic ways to find workable solutions for such deployment (see Paper 3). The analysis results are, then, reported to decision-makers via DDU for further processing. DAC provides essential requirements for generating scenarios and finding decision alternatives in NM. Figure 6.5 demonstrates the conceptualization of DAC in the planned humanitarian DSS.

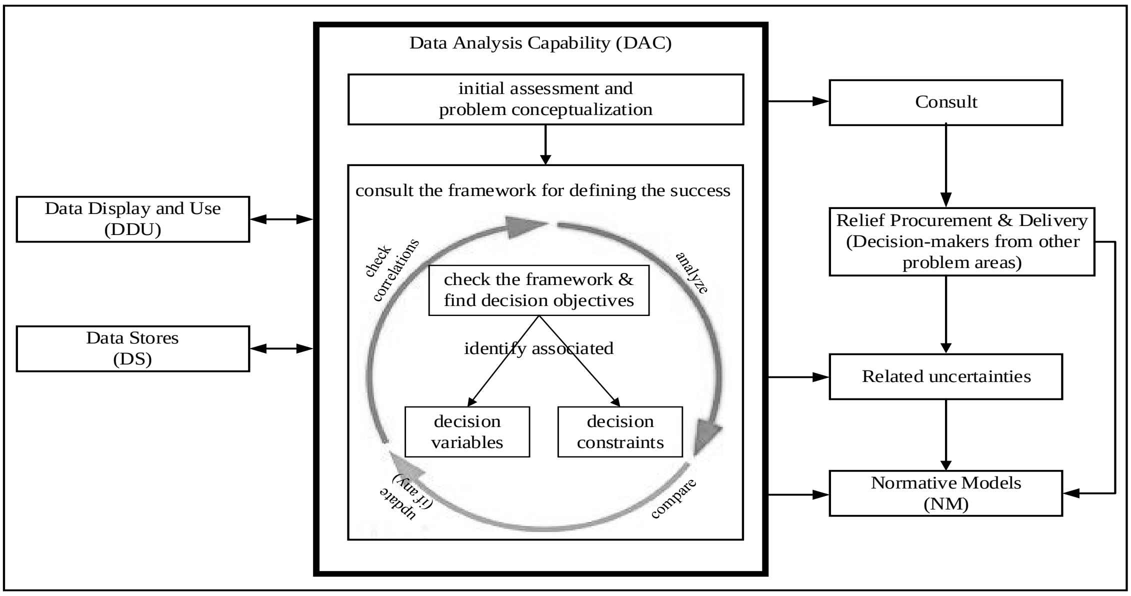


Figure 6.5: The conceptualization of the *data analysis capability* phase

Normative models address the DU issue of HRD–DM. This phase takes analyzed decision factors from DAC and inputs decision-makers from other problem areas to produce necessary arrangements for a joint, concurrent venture to fulfill the stated needs. Based on such inputs from other problem areas and selected decision factors, the mARD approach (proposed in Paper 2) is exploited to create and explore plausible scenarios necessary for identifying decision alternatives, priorities, and applicability. In this approach, the iterative process of scenario generation and alternative selection were restricted to limited operational time and limited iterations for supporting HRD–DM. The identified, related uncertainties (from DAC and external decision-makers) also affect scenario generation and, thus, process iterations and decision alternative selection.

However, the generated decision alternatives are influenced by the related uncertainties jointly identified by decision-makers involved in the process. In such situations, they are supported by the existing knowledgebase (DS) and final assessment from decision-makers, domain experts, researchers, and stakeholders. To assess the deeply uncertain field situation, the analyzing team requires adequate data on the circumstances, the operating field conditions, updated demand, weather, distribution alternatives, time, social capital information on forecasted demand notes, etc. Hence, to confirm their participation, decision alternatives are also assessed by the decision-makers from other problem areas (through DDU). The NM phase is depicted in Figure 6.6.

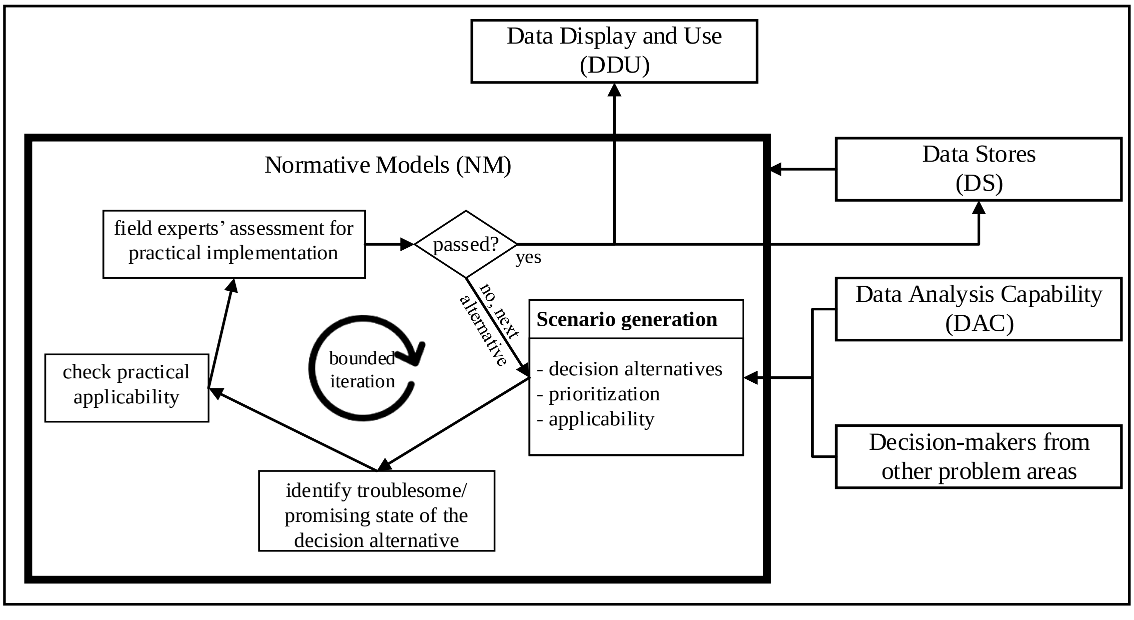


Figure 6.6: The conceptualization of the *normative models* phase

The data display and use phase receives the prioritized decision alternatives from the NM, each of which is scrutinized for its robustness and adaptive stability against the considered demand calls from the field and quantitative data from the DAC phase. For robustness, the respective decision alternative is examined to identify its troublesome/promising nature, adaptability, and practical (pragmatic) applicability. As soon as appropriate robustness and adaptability are achieved, the selected decision-alternative is assessed by experts in the field. If approved, the distribution plan is shared with decision-makers in other problem areas for relief procurement and delivery with enough information on the entire process (selected FLs, allocated resources, transportation, etc.). Here, each problem area performs its respective duties to process the procurement order and deliver relief goods as planned (to selected warehouses and distribution centers or directly to distribution points).

As soon as deploying arrangements are finalized, the distribution centers share customized distribution plans with associated distribution points. Coordinators in these points receive information about targeted beneficiaries (everyone, elderly, children, women, sick/pregnant, etc.), type of relief items (heavy, lightweight, food, garments, etc.), and distribution time and place. Such advanced information assists distribution centers in becoming well-prepared with necessary arrangements for decided categories. However, the assessed demand information is immediately publicly forecasted to inform neighboring communities, so they may meet initial demand—thus, maximizing coverage. These social elements of the IS artifact are discussed in the next chapter. Figure 6.7 visualizes the activities of the DDU phase.

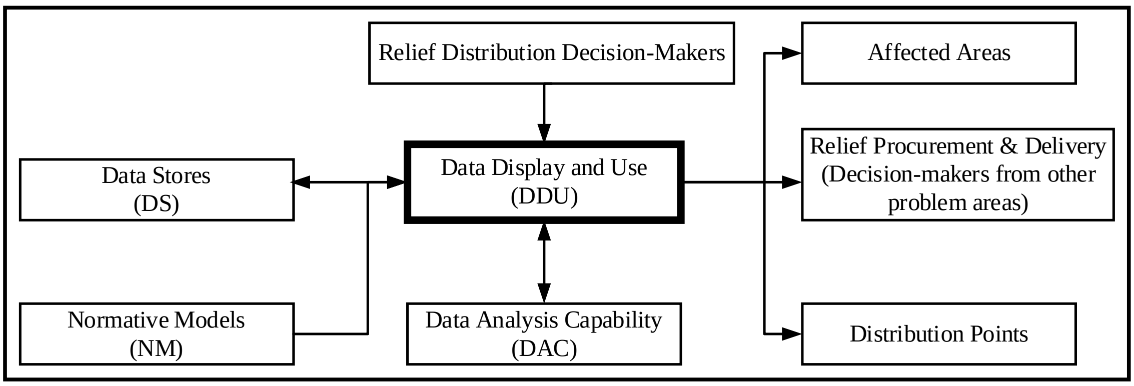


Figure 6.7: The conceptualization of the *data display and use* phase

Three management systems—database management system (DBMS), model-based management system (MBMS), and dialog management system (DMS)—are necessary for processing acquired and generated data. DBMS is dedicated to managing massive, disaster-related datasets in DS. It can control the disaster database, process users' (decision-makers and MBMS) queries, and provide formatted data to accelerate developing alternate models for faster decision-making in HRD. MBMS is responsible for managing multiple decision alternatives (generated in NM) influenced by numerous decision factors handled in DAC. DMS manages dialogs between external and internal participants through a communication interface between users and the system functionalities. It can control negotiations among decision-makers from different problem areas and with suppliers in the procurement process for relief operations.

The final DSS model is structured by accumulating all the components and their functionalities described above. The model, articulated in Figure 6.8, demonstrates the information and social aspects of an IS artifact. The information artifact presents how data should be processed and analyzed to generate meaningful outcomes for solving HRD–DM problems, and the social artifact visualizes the participating group of individuals who support such decision-making and its execution. The information aspect has been articulated in this section by discussing the phases of the DSS model, and the social elements will be discussed in section 7.1.1. Based on the already presented functionalities of each component, the model demonstrates a holistic view of the overall activities a decision-maker should perform to achieve support in HRD–DM.

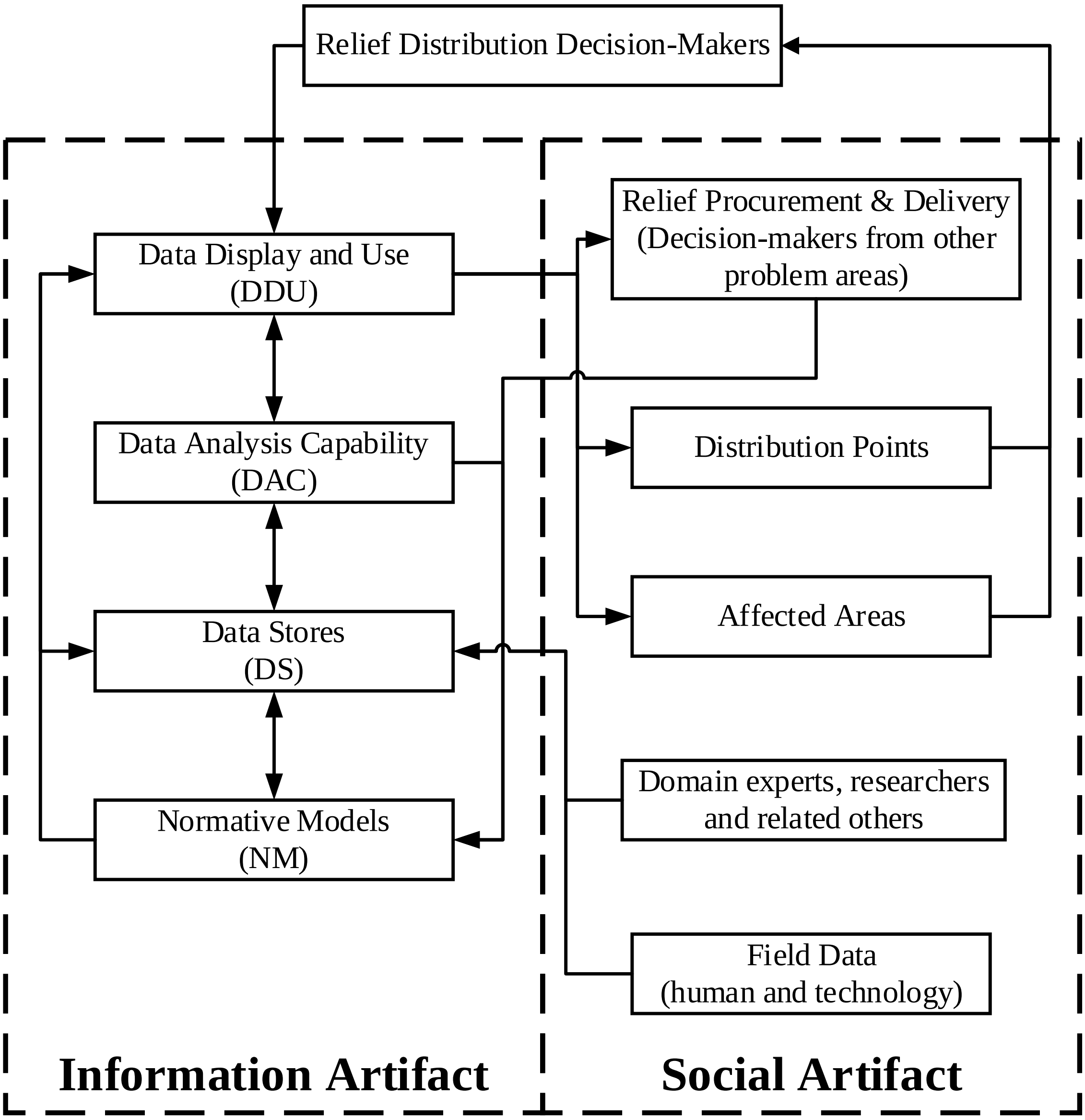


Figure 6.8: The final DSS model for HRD–DM

A functional model of the new humanitarian DSS is portraited in Figure 6.9. It is a task model, visualizing the functionalities of representative decision-makers (the users) for achieving their goals (Coutaz and Calvary, 2012). It also represents simplified interactions and communication between the user and four structural system components. The readers and/or audiences external to the modeled system can easily visualize its performance when implemented (Power, 2014). This holistic understanding is sometimes called a *use case diagram* in the system development literature.

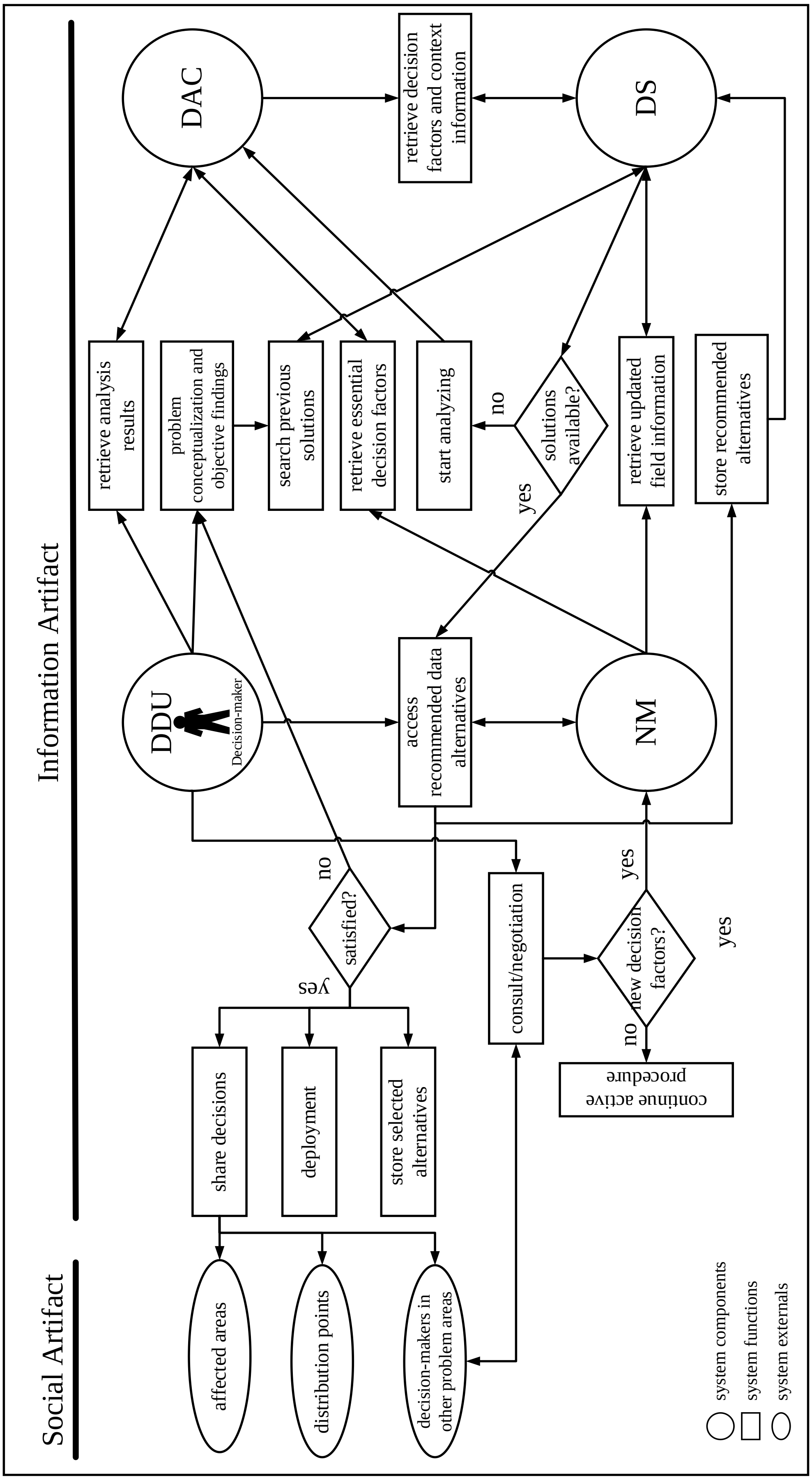


Figure 6.9: A functional model for the proposed humanitarian DSS

A decision-maker initially assesses a demand call and conceptualizes the problem. After understanding the achievement objectives, s/he searches the DS for immediate solutions. If none are available, decision analysis is performed via DAC, which retrieves essential data from the DS, such as identifying decision variables and constraints and contextual issues specific to the targeted disaster. Necessary correlational analysis, comparison, and updating is conducted here, and the outcome is forwarded to the NM to generate decision alternatives. The DAC result is also consulted with decision-makers from the other problem areas to identify their concerns and related uncertainties and support the NM in performing its tasks. To provide support with decision alternatives, the NM receives additional (updated) data from the DS concerning the operating environment, such as social capital information, deploying field conditions and accessibility, FL access and inventories, available transportation means and routes, safety, and security, and so on. After processing all data from different sources, the NM recommends multiple decision alternatives to the DDU, along with some crucial and specific information. The decision-maker at the DDU then decides the best match and takes the necessary actions for deployment. Recommended and selected alternatives are stored in the DS for future use. If no choice satisfies the need, the problem must be reconceptualized and the process must begin again.

6.6 Additional Findings

This section presents some specific findings concerning challenges or objectives between practitioners and researchers and addresses some existing research gaps. It also discusses some social and policy aspects of decision-making, which are not directly linked to the RQs but affect practical decisions in HRD.

6.6.1 Perception of Challenges or Objectives

This study revealed some challenges between HL researchers and practitioners. Academic research in HL mostly focuses on making optimization decisions by applying various context-specific mathematical models. Therefore, a particular model is rarely used in multiple contexts, although they are sometimes evaluated or validated by being implemented in practice. When discussing the matter with the practitioners (through interviews), their absence in the model development process was identified as a prime reason for having such context-specific usage. They remarked that their thoughts and inputs are seldom reflected in the literature and, thus, are also rarely reflected in practice. After publishing their work in academic outlets, researchers rarely continue communicating with the practitioners to upgrade the published pieces.

On the other hand, HL researchers concentrate more on addressing issues in the FL problem area, which is the only problem area that is jointly studied with other problem areas. In such cases, researchers foster the objective of solving the problems related to FL first and then move on to address the issues in the conjoining problem area. However, this is not the case for practitioners who concentrate on practical solutions to send relief goods to demand points and distribute them among beneficiaries. They prefer solving transportation problems first. According to the practitioners surveyed in this research, temporary and/or additional staging areas (warehouses) can be allocated, but unavailable transportation and inaccessibility to the affected regions cause the relief drive to fail or perform inadequately. Hence, there is no alternative to collaborative work (between practitioners and researchers) for productive and successful relief operations.

6.6.2 Addressing Some of the Existing Research Gaps

This study addressed some of the research gaps identified by Jabbour et al. (2019) and McLachlin and Larson (2011). In their recent review paper, Jabbour et al. (2019) detect that most of the analyzed research in HL is theoretical, and they argue for more practitioner-focused research in this community. The present dissertation mainly addressed this demand by modeling the aimed humanitarian DSS for HRD–DM. System requirements were elicited, not only from the literature, but also from practice. As discussed in Chapters 3 and 4, humanitarian experts validated the literature-based decision factors in this research and recommended missing (but important) factors, which they further cross-validated. Their ratings were statistically analyzed to define and prioritize the interconnections between problem areas and to produce a prioritized list of decision factors and their correlations. Thus, I ensured the practitioners' participation in finding system requirements and modeling the DSS towards its development. By discussing two specific earthquake cases (Nepal [2015] and Indonesia [2018], Chapter 4) and using mixed methods for data collection and analysis, this study contributed to minimizing two salient gaps reported by Jabbour et al. (2019): understanding disaster types and research methods.[35]

Furthermore, together with leading practitioners, McLachlin and Larson (2011) identify functional relationship-building challenges in HSC with four groups of key actors: donors, humanitarians, the public, and beneficiaries. By considering these issues as the components of the social artifact (see Figure 6.8), this study addressed all the relationships except the challenges with donors, since this research focused on the downstream part of HSC, where donors' activities are not handled (see Figure 2.2). For concurrent activities and effective decision-making in HRD, I argued that proper communication and interaction should be maintained between decision-makers in all six identified problem areas: HRD, FL, RSC, IM, Transp, and Sched. The responders in the field were also incorporated in the process and shared customized information to facilitate deploying the decisions made. Forecasting demand information to the public can be incorporated into the decision-making process to achieve a better social capital response from neighboring communities. The process can also include policies of sharing the distribution plan with beneficiaries and standardizing relief packages to reduce social tension and serve demand accordingly. These social and policy aspects are encompassed in Paper 5 and are briefly discussed in the following subsections.

6.6.3 Social Aspect

It became clear from the interviews and surveys that the social process of the affected areas plays a vital role in immediate disaster response. Many participants confirmed that the inhabitants from the neighboring communities were the first responders to affected people. In the first hour after a sudden disaster onset, they started rescuing, sheltering, and providing food and other necessities, while organizational support is still unavailable (Bhandari, 2014). So, while preparing the response, respective HRD centers can forecast the immediate demand to the neighboring regions. Thus, local communities can step onto the scene to support survivors with food, water, clothes, medicine, shelter, etc. However, these communal services should be adequately monitored and coordinated, while allocating funds for procuring relief items. Otherwise, delivered relief goods may remain unused or

[35] Please refer to this article for a detailed discussion of the two addressed gaps, as well as four other gaps.

become surpluses in the HRD center and cause unexpected burdens for the decision-making process. To achieve mutual benefits, Dynes (2002) suggests incorporating collective societal activities (i.e., social capital) in disaster response. Bhandari (2014) enhances this concept by recommending its inclusion in the decision-making process for socially equitable HRD, regardless of the different classes and ethnic backgrounds of the affected people. The distribution centers should obtain adequate knowledge about the social capital of neighboring regions and communities of the affected areas to understand their supporting and influencing capacities in the HRD process.

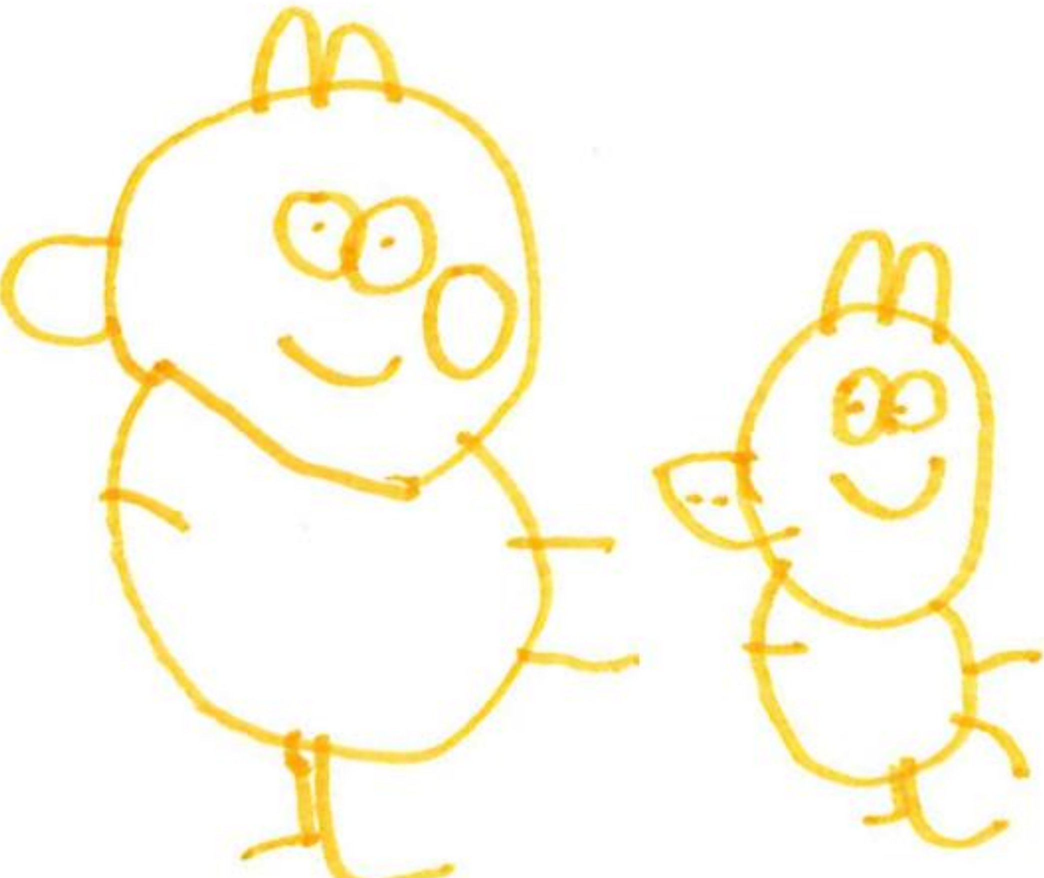
6.6.4 Policy Aspect

HRD operates in chaotic environments, where social tension is palpable. If somehow fueled, it could cause uncontrollable situations for HRD. Hence, the present findings revealed the importance of formulating strategies from the policy aspect to lessen or avoid (in some cases) such anxiety. To do so, practitioners, through the Delphi study, recommended taking the following actions when preparing a deployment.

- Share a customized distribution plan with the beneficiaries well ahead of the distribution time.
- Announce distribution center access times that are suitable to the recipients.
- Provide adequate logistical support in the HRD center.
- Prioritize remote and severely affected communities.
- Prepare and distribute standardized relief packages.
- Digitalize the responding system to control and accelerate public participation.

6.7 Chapter Summary

This chapter identified decision-making problem areas in HL operations and their encompassing decision factors, along with how they influence HRD–DM. By applying concepts from the HSC, decision analysis, and DU disciplines, this chapter revealed the strategies for supporting such decision-making. It addressed the MRQ and proposed a humanitarian DSS model (Figure 6.8, an IS artifact) by receiving support from the three SRQs. It also presented some perceptions on challenges/objectives between researchers and practitioners, explained how this study addressed some existing research gaps in HL, and described why incorporating social and policy dimensions are important for making and successfully implementing effective decisions.



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7 Contributions

This chapter discusses the contributions of the dissertation. Based on its empirical findings, it offers implications to scientific knowledge, research methods, and practice. Theoretical and methodological implications are based on the existing theories in the literature, while practical implications mainly include decision factors necessary for supporting HRD–DM. By consulting the prioritized list of decision factors and the interconnection between problem areas, HDMs can accelerate decision-making for distributing relief goods among beneficiaries. All the theoretical, methodological, and practical contributions are outlined in the following subsections.

7.1 Theoretical Contributions

This dissertation enriches the scientific knowledgebase by offering four main contributions to the HL community. Table 7.1 lists these contributions, which are further discussed below.

Table 7.1: Summary of theoretical contributions

#	Contributions	Description
1	Modeling the *proposed humanitarian DSS*	• Provides a comprehensive set of guidelines for system modeling: user requirements, system features, and system development process guidelines. • Structures in-system information flow and information sharing (interactions) between decision-makers in different problem areas. • Conceptualizes information and social artifacts towards an IS artifact development.
2	Framing HL as an *ecological system*	• Identifies six problem areas (HRD, FL, RSC, IM, Transp and Sched) and their associated decision factors. • Defines interconnectedness among those problem areas. • Demonstrates correlations between decision factors and prioritizes the most influential ones.
3	Conceptualizing *DU* in HL research	• Proposes an *mARD* technique for identifying decision alternatives based on DU. • Recommends that the approach must be bounded by a shorter timeframe and a limited number of process iterations.
4	Elaborating the *pragmatic approach* for HL research	• Addresses humanitarian issues, including dynamic, practical, and contextual problems. • Emphasizes what works and what does not. • Recommends the mixed-methods approach to generate effective solutions. • Articulates the *action and change* concept for achieving values in the ethical and moral discussion on the system.

7.1.1 Modeling the Planned Humanitarian DSS

The model presented in Figure 6.8 for the planned humanitarian DSS is considered the first contribution of this dissertation. It articulated comprehensive guidance to the system designers by demonstrating information flows and interactions for supporting HRD–DM. Although an IS artifact has three parts (technology artifact, information artifact, and social artifact), this contribution can be conceptualized for only information and social artifacts (see Section 2.1 for a detailed discussion). Both dimensions were framed in Figure 6.8 and described in Section 6.5—the information portion in detail and the social artifact in brief. To demonstrate the initial dimension, a functional model was depicted in Figure 6.9. It presented the respective tasks for the system and the decision-maker (as a user). This section elaborates on the *social* dimension of the proposed DSS.

The *social artifact*, in the model, was created by incorporating relationships or interactions between decision-makers from multiple problem areas, thereby achieving individual decision objectives and serving the ultimate purpose of successful HRD deployment. This artifact also includes fieldworkers (e.g., staff members, volunteers, informants, other responding teams, etc.), who provide valuable information about the operating environment and/or operational support to the deployment. Including the social aspects described in 6.6.3, the model conceptualized the following notions recommended by the domain-experts.

- A customized distribution plan should be shared with the beneficiaries well ahead of the distribution time, so they can prepare themselves. For example, if the recipients are informed that the relief goods to be delivered are heavy, they can bring helping hands to the points of distribution. Furthermore, if they know the distribution categorization (e.g., elders, children, women, sick people, or pregnant women), less crowded situations can be achieved in the distribution points.
- Although they are typically located at a distance, the most affected or vulnerable communities should be prioritized in disaster responses. The practitioners in the present Delphi study reported that such prioritization is not widely practiced. Most NGOs deploy their distribution operations near the center of the affected area or in the easily accessible regions. They occasionally do this to gain hidden financial benefits since donors are usually reluctant to allocate extra funds to cover extended arrangements. Thus, the remote communities are

left unsupported or with limited support, which sometimes causes a higher death toll and fuels social tension.

- The practitioners found it complicated to operate a distributing process if unstandardized (compared to nearby distribution points) relief packages are prepared. Other responding teams can be contacted to learn what goods are being distributed in the neighboring regions. Otherwise, duplicate or fraudulent distribution can be triggered.
- When the distribution is being planned, the recipients should receive adequate logistical support at the distribution center. If decision-makers plan to cover multiple communities, they should consider the safe return home of the beneficiaries (coming from the furthest community) with relief goods before sunset. Again, if elderly citizens, sick people, and/or pregnant women are targeted to be served, some special arrangements should be prepared for their convenient accessibility—for instance, shorter waiting times, shade, chairs, etc.
- For effective HRD, it is essential to announce a suitable time for accessing the center. Otherwise, respondents may experience surplus relief goods or lack of storage for essential ones at the distribution centers. It can also cause a higher operational cost.

7.1.2 Framing HL as an Ecological System

Establishing HL as an ecological system is the second contribution of this dissertation. In this respect, I identified the problem areas and their associated decision factors by studying mathematical models with practical implications. Few studies in the literature were found to focus partially on such requirements (e.g., Gutjahr and Nolz, 2016; Peres et al., 2012; Roy et al., 2012). However, a complete study incorporating all the three categories of decision factors (decision objectives, variables, and constraints) in all six problem areas (HRD, FL, RSC, IM, Transp, and Sched) is rare, as is research concerning their interconnectedness. The existing decision support models operate individually in their specific problem areas without providing any (procedural, methodological, knowledge, etc.) support to other models. Although Roy et al. (2012) recommend concurrency between problem areas, the process requires in-depth research and understanding.

To support such concurrent activities, all problem areas should achieve their negotiated operational objectives to maintain the distribution networks. Thus, I examined all problem areas that affect HRD, not only to identify their associated decision factors but also to quantify their influence in the decision-making process. This quantification of interconnecting impacts was recognized as an operational ecosystem for HRD. By studying the ecosystem, decision-makers in HRD can initiate negotiations with decision-makers in other problem areas. To facilitate such discussions, I articulated how each decision variable and constraint correlates to each decision objective for supporting effective decision-making. Decision-makers should carefully select essential decision factors since a positively influencing decision variable or constraint for achieving a specific objective may negatively influence other goals in a problem area or among problem areas. Therefore, decision-makers in affected problem areas should consult their contribution to HRD operations, which can be fed as input into the system. Such conceptualizations would help HL researchers (and system designers) understand the extent of the influence other problem areas have in HRD–DM and, thus, help them decide how much (and what) to emphasize in the DSS design. Therefore, instead of separate deployment, all problem areas should be operated concurrently in the HSC downstream presented in Figure 2.2.

7.1.3 Conceptualizing Deep Uncertainty in HL Research

DU conceptualization in HL is the third contribution of this dissertation. Since this concept is new to HL research, few researchers have defined it in their studies (e.g., Comes et al., 2013; Klibi et al., 2010). The present investigation identified that none of the available approaches to DU is readily applicable to HL problems. Traditional methods are designed to address longitudinal issues, in which researchers have ample time for data collection and analysis. However, HL researchers are required to make rapid decisions with limited data. They always suffer from information unavailability, inaccessibility, or inappropriateness for the disaster and demand. The presence of multiple decision-makers in multiple problem areas with numerous decision-making models also complicates the procedure for addressing uncertainty since no clear understanding is available concerning models' decision factors and alternative outcomes (Ansell et al., 2010; Baharmand et al., 2015).

Therefore, this dissertation generated a holistic understanding of DU in HL research and proposed a potential approach to address it in HRD–DM. The study recommended both adaptive and robust approaches to solve decision-making problems in this domain. The former approach supports policy adaptation for achieving operational objectives, while the latter supports encountering plausible scenarios for generating decision alternatives. Therefore, along with necessary modifications in the procedure, I contended the *mARD* technique as the most apposite mechanism for addressing DU in HL decision-making. The crucial changes are listed below and elaborated in Paper 2:

- Be bounded by time.
- Be bounded by an acceptable iterative threshold.
- Incorporate an effective data transformation technique.
- Handle unidirectional operations.
- Provide quality information.
- Incorporate decision factors (objectives, variables, and constraints).

7.1.4 Elaborating the Pragmatic Approach for HL Research

Theorizing the philosophical underpinning of HL research is the final contribution of this dissertation. Decision support in humanitarian logistics operations is mainly based on mathematical models, which have a limited scope in terms of decision factors (Richardson et al., 2016). Additionally, available studies on supporting decision-making are specific to particular contexts or problem areas. However, this research recognized that decision-making for distributing relief goods is a complex, multidisciplinary task. It requires rigorous thinking and critical analysis of the existing literature for organized, well-planned, and practical decision-making support.

This empirical study revealed that decision-makers solve practical decision-making problems pragmatically. To identify working solutions and achieve ethical and moral values, they utilize referential support and conceptualize the notion of limited *action and change* in the process. Although articulations of such concepts are rare in the literature, I contended that the pragmatic approach is appropriate for studying HL problems. It provides a richer understanding of the topic under investigation by identifying core themes and their interrelationships: problems' roots, development, assumptions, research strategies, methods, and extensions. Therefore, this examination, presented in Paper 3, provided guidelines for studying the philosophical underpinnings of HL research and methodological guidance to develop the envisioned DSS.

7.2 Methodological Implications for Research

To identify decision factors for HRD–DM, this dissertation used the Delphi method, which is recommended for exploratory research similar to this study. Using the Delphi approach is a common practice in the IS discipline (Päivärinta et al., 2011). The guidelines provided by Okoli and Pawlowski (2004) have largely been adopted by IS and HL researchers, where data is collected through brainstorming (see, for example, El-Gazzar [2016], Gossler et al. [2019], Moe [2015]). However, although rare, literature review findings are also used as input for Delphi studies (see, for example, Melnyk et al. [2009], Richardson et al. [2016]). In the former study method, experts' suggestions lead the research toward listing critical issues to solve the targeted problem, while, in the latter, experts participate in completing the already generated (literature-based) list.

This research incorporated both processes: literature review findings in the first round of the study and brainstorming results in the second round (detailed in Chapter 4 and summarized in Paper 5). The structured questionnaire in the first round of the e-survey gave the panelists the opportunity to suggest decision factors that they missed in the list. Instead of answering the survey, they were also given a choice to participate in open-ended or guided interviews. To identify new decision factors, I analyzed the responses to the first survey—that is, the textual and interview data—based on the principles of content analysis in grounded theory: open, axial, and selective coding. However, this entire activity could not be described as using the grounded Delphi method (Päivärinta et al., 2011) since it did not incorporate findings from the extensive literature review. Therefore, I contend that the research approach applied in this study provided a deeper and better understanding of the requirements necessary for modeling the envisioned DSS system design for HRD.

7.3 Implications for Practice

The contributions of this research to the practice are two-fold: decision-making and execution in the field and software system development. These dimensions are discussed in the following sections.

7.3.1 Decision-Making and Execution

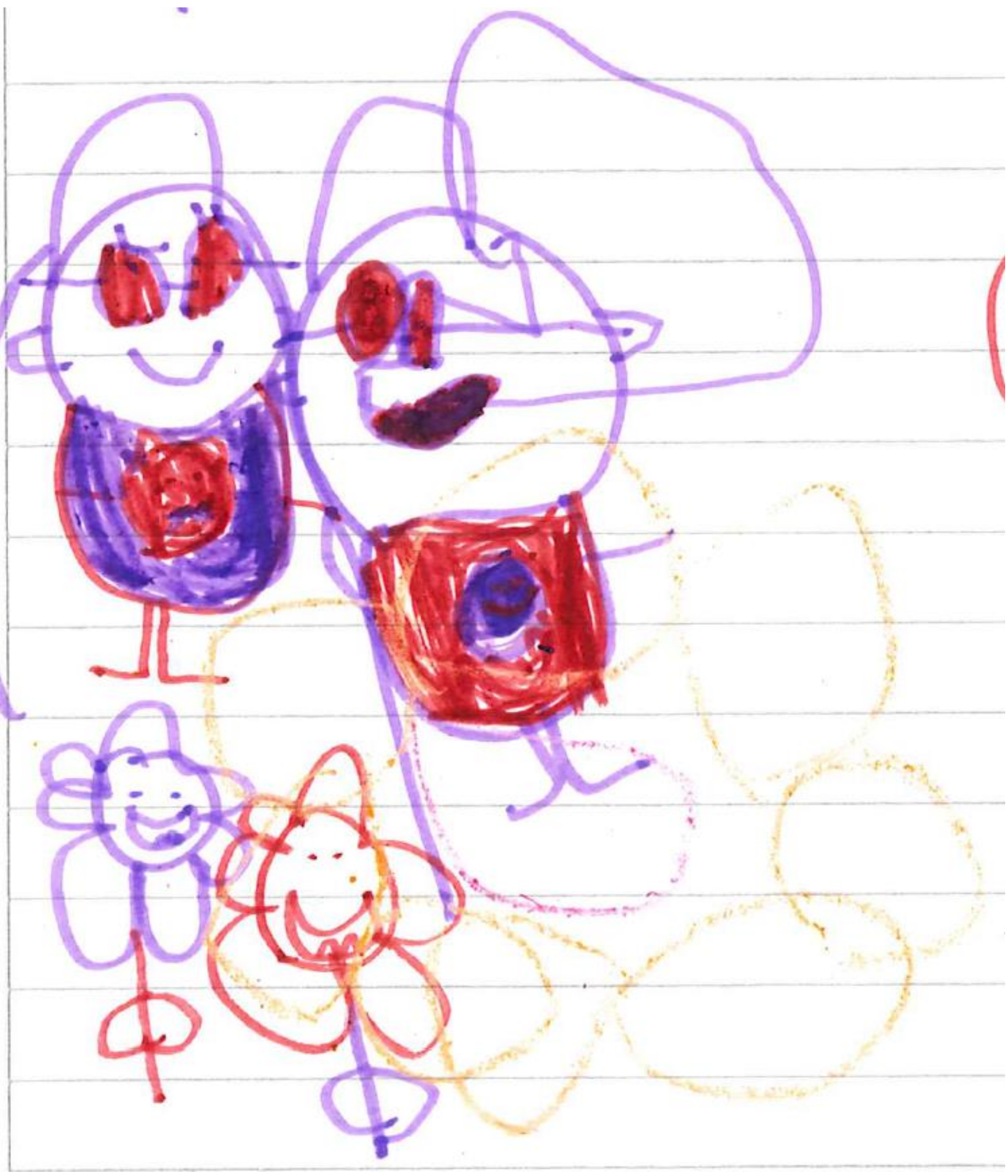
This dissertation provided a set of salient (and validated) decision factors, their correlations, and their encompassing problem areas. I highlighted the importance of examining the interconnectedness of problem areas and concurrent activities for successfully deploying relief operations. These concepts can be used to develop strategies for providing faster decision-making support in HRD by suggesting essential decision factors to decision-makers. Via consulting the proposed operational ecosystem, they can understand how, and how far, different problem areas are interconnected in the distribution procedure. This holistic understanding will form a basis for effective negotiations between decision-makers in the six problem areas—balancing objectives to gain a precise (single) goal in combination. By sharing the customized version of the decisions made in the center (as proposed in the DSS model) with beneficiaries and with ground staff at HRD points, effective HRD can be planned and executed.

7.3.2 Software System Development

For system prototyping and development, the models proposed in the dissertation (and in Papers 2–5) will assist system developers with understanding the HRD process and its consequences. The findings from this research will provide them with an idea of the key contributing actors (decision-makers in the identified problem areas) and the interactivities among them. They can also achieve an in-depth understanding of the social and communication infrastructure in disastrous situations. Thus, having a system that rapidly analyzes the demand, determines necessary decision factors, and applies them to suggest suitable decision alternatives will accelerate HRD–DM. The identified decision factors in this research can be transformed into software requirements (functional and non-functional) for prototyping and system development. These vital, influential factors can be prioritized to form the basis of a typical *must–should–could* assessment. After creating a working prototype, convenient features can then be added to the software system development cycles.

7.4 Chapter Summary

To support decision-making in HRD, I applied an exploratory research approach, which took both HL researchers and practitioners onboard. According to the interviewed panelists, literature contents are not usually shared with practitioners. They even argued that their understandings, opinions, and observations were seldom reflected in the research literature. Hence, a methodological approach was taken, requesting them to evaluate the decision factors from the literature and suggest some new ones from the field. Thus, a more comprehensive set of affecting decision factors was gathered for modeling the HRD–DM support. However, this would not have been possible without proper guidance from the IS research literature. Therefore, I contend that the research approach used in this study provides a holistic and better understanding of IS research in operational decision-making in HL.



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8 Conclusion, Limitations, and Future Work

This dissertation is one of a few IS studies combining HL and DSS domains to investigate humanitarian decision-making problems (see Altay and Labonte, 2014; Comes, 2016; Comes and Van De Walle, 2016). This chapter summarizes the main findings of this dissertation and then points to its limitations. Finally, it offers recommendations for future research, not only to mitigate the mentioned weaknesses but also to develop the ultimate product—a functional, computer-based, humanitarian DSS.

8.1 Summary

This dissertation aimed to support HDMs with effective decision-making in HRD under DU. To respond to sudden-onset natural disasters by establishing a bridge between research and practice in IS, HL, and DSS domains, different conceptual, theoretical, empirical, and analytical work was conducted in this research. Its contributions were further validated against practical relief operations, either by the international research communities or by experts from the field. The entire process was examined through three SRQs towards an MRQ. The study also investigated and minimized the gap between academic researchers and practitioners.

The MRQ, raised in Chapter 1, concerned modeling the DSS by gaining a holistic understanding of HL and its operations, especially in HRD: *"How can decisions in HRD be supported under DU?"* To be addressed, the MRQ was divided into three SRQs: (1) *"What are the significant research challenges for operational decision-making in HL?"*, (2) *"How can DU be characterized in HL for HRD–DM?"*, and (3) *"What are the requirements for supporting HRD–DM?"*. SRQ 1 covered background studies to understand the problem and identify research challenges. SRQ 2 covered a detailed study of DU and its applicability in HL research. SRQ 3 covered the philosophical underpinnings of this research and then applied that understanding for requirement elicitation and validation.

The findings indicated that improved disaster response is still at the level of concept development, although advanced HL research has been conducted in the last five years (Baharmand, 2018). HRD is rarely recognized as a multidisciplinary research problem. The problem areas it encompasses are always studied individually to achieve standalone objectives; the understanding of concurrency is seldomly discussed in the literature. Although modern technology and information support are available, operational decision-making in HL suffers from severe uncertainties and beneficiaries' dissatisfaction.

So, to address these challenges and answer the MRQ, I understood this research problem at its root—exploring my personal experience with the 2007 super cyclone Sidr relief operation, related information flows, and initial literature studies. This understanding assisted me in answering SRQ 1 by identifying three significant challenges for this research: ways to address DU, decision analysis for an operational response, and rapid HL modeling. Paper 1 articulates this identification and establishes the foundation for the study (see Figure 5.1). These challenges were addressed in SRQs 2 and 3 to formulate IS support for HRD–DM. Respective domains were studied in Chapter 2 to understand their conceptual, theoretical, empirical, and analytical works.

Paper 2 dedicatedly concentrates on addressing SRQ 2—conceptualizing DU in operational decision-making in HL. To accomplish this, I studied the notion of DU and its available approaches in detail. Although it has potential applicability, the DU concept is rarely discussed in HL research. Such an in-depth examination assisted me in proposing an mARD approach to address HL problems. By limiting process iterations for generating decision alternatives, the mARD system would support the DSS in coping with dynamic situations and performing well in all conditions with more coverage.

Decision analysis was conceptualized as identifying the requirements for modeling the proposed humanitarian DSS: decision factors (objectives, variables, and constraints), associated problem areas, and their interconnectedness. For requirement elicitation, I planned to identify state-of-the-art decision factors for HRD–DM and validate them with a panel of expert practitioners. To achieve methodological support to execute this plan, I investigated all available design philosophies against decision support type IS research. This assisted me in developing an understanding that practical problems in HL should be addressed pragmatically to support HRD–DM in the best way. Paper 3 details this inquiry, and Section 4.1 summarized it. In combination with requirements elicitation and validation, elaborating the philosophical underpinnings of this researcher also contributed to addressing SRQ 3.

Both qualitative and quantitative methods were mixed for this study. An SLR was conducted to propose a comprehensive framework, incorporating 63 decision factors from six problem areas: HRD, FL, RSC, IM, Transp, and Sched. However, to address HRD problems effectively and efficiently, it is essential to understand how decision-making in HRD is affected by decision-making in the other five problem areas. Thus, decision-makers can negotiate their participation in these ventures and serve needs as decided. This notion was theorized as an operational ecosystem for distributing humanitarian relief goods. The SLR and its results were reported and discussed in Chapter 3 and are summarized in Paper 4.

The identified decision factors were then validated by academic and field experts through a Delphi study. Panelists were given the opportunity to choose whether they wanted to answer the survey questionnaires or participate in interview sessions. In either case, they rated the provided (literature-based) decision factors and recommended some other factors that were not uncovered in the literature but were crucial for practical decision-making. After two rounds of Delphi validation surveys, I proposed a combined (literature-based and expert-preferred) list of 22 critical decision factors for HRD–DM. To provide researchers and decision-makers with an understanding of the effect of each variable and constraint on achieving each decision objective, their correlations were also studied. Additionally, the literature-based operational ecosystem was validated by the panel to discover its applicability in practice. Although a summarized list of vital decision factors was provided, I recommend that HDMs consult the entire prioritized list to better comprehend the consequences and respond efficiently and effectively. This empirical study and its outcomes are conveyed in Paper 5 and were presented in Section 4.3.

After combining the outcomes from these SRQs, the MRQ was finally answered by proposing an operational humanitarian DSS model for HRD–DM. The findings from this dissertation and the published articles scientifically contributed to the domains of DU, decision analysis, and HSC. This research significantly contributed by demonstrating how IS research can support humanitarian decision-making under DU. Considering the underlying methodologies and the dominance of agile approaches to software development, the research reflected how humanitarian ISs are currently understood and designed. Therefore, the artifacts created in this Ph.D. project did not follow a classical, requirements-driven approach but, rather, employed a participative and agile approach. It built an understanding of incorporating user requirements changes into the process and responding to them through its collaborative components and relationships with its environments (Lee and Xia, 2010; Sheffield and Lemétayer, 2013). To accept and embrace such requirement changes, agile approaches are designed based on an iterative or adaptive lifecycle (Sheffield and Lemétayer, 2013). Although it was another important and convincing result of the work, I did not mention this concept directly in the dissertation but verbally presented it by demonstrating the multidimensional operational concurrency in HRD (Lee and Xia, 2010). I avoided making the presentation too technical since the technological part of this IS artifact was not covered in this study. Future researchers may take this work further ahead by obtaining benefits from its findings and outcomes. They can also build upon the presented system to provide IS support to HL for responding to large-scale, sudden-onset natural disasters. The limitations of this study and suggestions for future research avenues are discussed below.

8.2 Research Limitations

As with any study, this research has limitations. Therefore, this section covers those limitations, as well as the challenges the study faced while enhancing IS research in the HL community.

Static Research Period. Since this research was part of my doctoral study, I had to follow prefixed deadlines. Thus, it is possible that I was unable to capture all effects at the *right* time. This type of HL research may require a more extended period to perform a chain-of-operations: literature analysis, theory development, empirical testing, system modeling, requirement analysis, prototyping, evaluation, system development, and practical implementation.

Data Collection (SLR). The decision factors resulted from an extensive and systematic analysis of related literature collected from Scopus and IEEE Xplore in the last half of 2016 and evaluated at the beginning of 2019. Thus, the experiences presented here may differ for the period following data collection. It is also possible that I missed some important works due to limiting not only the search databases but also the set of keywords and their combinations. Since only academic journals and conference papers were reviewed, this research may suffer from the limited generalizability of research directions, missing important gray literature.

The filtering criteria may also have been unjustified in discarding some articles, and, hence, some crucial factors could have been lost. Thus, employing new analysis techniques may lead to somewhat different findings for the listed decision factors and the operational ecosystem for HRD.

The Framework with Decision Factors. HRD decision-makers must be cautious when analyzing demand calls and selecting necessary decision factors. Instead of providing them with problem-sets analyzing guidelines, this research assisted them with a framework of decision factors and correlations. On the one hand, the proposed framework is practically extensive (as a whole). On the other hand, some cases in the analysis were observed to have a single decision factor listed in all three categories of decision factors, even in a single problem area. The characteristics of contextual problem setting may be the fundamental reason for such placement. A more in-depth investigation is required in the context of the reviewed models (in the literature) to obtain alternate or additional reasons for this observation.

Data Validation. The Delphi study recruited a panel of HL experts to evaluate the decision factors from the literature for HRD–DM and propose new factors from the field. Although the board consisted of members from multiple continents, the experts from Indonesia and Nepal dominated the panel. Since the empirical evaluation was conducted in South and Southeast Asia, the decision factor insights could somewhat differ from those in other parts of the world, and potential biases may exist. Again, switching to different relief organization types may also affect the study results. The sender–recipient problem is also always involved in communication, and this study was not free from it. Thus, quantified, subjective impressions or assessments may differ from what the panelists originally meant.

Information Flows. HDMs work under pressure in highly contextual and dynamic disaster environments, where DU in decision-making is apparent. They receive data from multiple sources, which is sometimes inadequate, improper, or excessive, and causes fluctuations in relief demand. Such dynamic needs create problems for maintaining the entire RSC to distribute relief items efficiently. On the other hand, the validating expert panel was the same in both survey rounds. Thus, the result produced was perhaps biased by the panelists' understandings, answering attitudes, and perceptions. Some differences might be found in the validated results if the panel was extended to further expert groups. Although the proposed models were developed by considering a good flow of information, they should undergo further empirical testing before being placed into the intended humanitarian DSS development.

Experts' Participation. Comparing to other IS Delphi studies, the Delphi panel for this research was relatively small. This was due to difficulties in accessing experts, their priorities and willingness, limited time for research contribution, communication language barriers, accessibility to computers and the internet, and organizational legislation. Although approved by academic experts, some participants found that the initial survey questionnaire was extensive and time-consuming. Some practitioners reported difficulties with the English content, while others stated that they had no access to computers or the internet at the survey time. Although I produced a non-disclosure agreement, some participants found it insufficient for their organizational legislation and, thus, did not participate. A higher participation rate could excavate deeper into the topic and explore various avenues to identify somewhat different findings.

The Proposed Model. Although aimed to develop a DSS for HRD–DM, this research ended up determining the information and social models for such a system. Due to limited time and expertise, discussing and modeling the technological part of the system was not covered in this dissertation. Hence, it became challenging to evaluate whether both models work as expected once the DSS is finally created and tested in a summative setting. Building such a system is not just a simple software developing project with extensive use of database management systems. It will require more research and iterative developmental work. For example, before beginning the requirement analysis for the humanitarian DSS, the proposed model may need further refinements, upgrades, and rigorous evaluations from practitioners. Such tasks would take time and require both resources and a group of potential researchers and experts from various disciplines.

8.3 Future Work

The contributions of this dissertation and its limitations offer opportunities for future research. In addition, this section proposes some further potential research avenues and trends through which future researchers can concentrate on enhancing and advancing the work in this field. The recommended future research avenues are presented subsequently.

Research Extension. The evaluation of the operational ecosystem revealed significant contradictions between science and practice in HL research. Scientific literature reported *Transp* as the least influential problem area for HRD–DM, while experts found it to be the most influential area. Additionally, when developing mathematical models for supporting decision-making, researchers followed no conventions for selecting decision factor elements. This investigation identified several cases in which a similar factor was considered in all three categories: decision objectives, variables, and constraints. Since these contradicting issues will affect the ultimate software product development, future researchers should concentrate on solving such challenges.

Digitalization. The responses from Nepali and Indonesian experts can be compared and further studied to understand technological advancement in humanitarian response. As the Nepali earthquake is three years older than the Indonesian earthquakes, problem-solving techniques and response activities in the latter case should be more technology oriented. Such a study will highlight how combinations of modern technology and experiences from previous disasters can potentially be applied for service digitalization in new cases. As described by the practitioners in this study, such conceptualization would extend the existing communication systems and bring changes to society and businesses.

System Model Evaluation. Before being analyzed for system development, the proposed model for humanitarian DSS design must be evaluated, both in the center and in the field. To gain a holistic understanding of combining different decision factors and solving decision-making problems, decision-makers should consult the proposed framework and select necessary attributes. However, as HL issues are highly contextual, the proposed model provides no clue about combining those attributes. Decision problems of similar types behave differently in different disaster contexts. Hence, the model must be tested in various problem sets or cases, evaluated, and modified where necessary. Therefore, to achieve consistency in the system design and its development, the dynamic nature of humanitarian operations should be considered and incorporated into the system.

IS Artifact (the final DSS) Development. As HL actions are sophisticated, practical, and contextual, human beings alone can do little to support survivors. They must be assisted by computerized ISs, which do not exist without SE intervention.

A research trend can be formed by combining SE with HL to prototype and develop the envisioned DSS for effective HRD–DM.

After validating the proposals from this study, decision engines can be developed with adequate mathematical formulations for decision-making. Then, the software system can be developed via sufficient prototyping and design experiments. After development, the system should be validated and empirically tested by both measurement instruments and practitioners. Before generalization and implementation, the system should comply with its operational specifications; otherwise, necessary changes must be made to upgrade the developed system. Figure 8.1 depicts future research directions for the final IS artifact (humanitarian DSS) development.

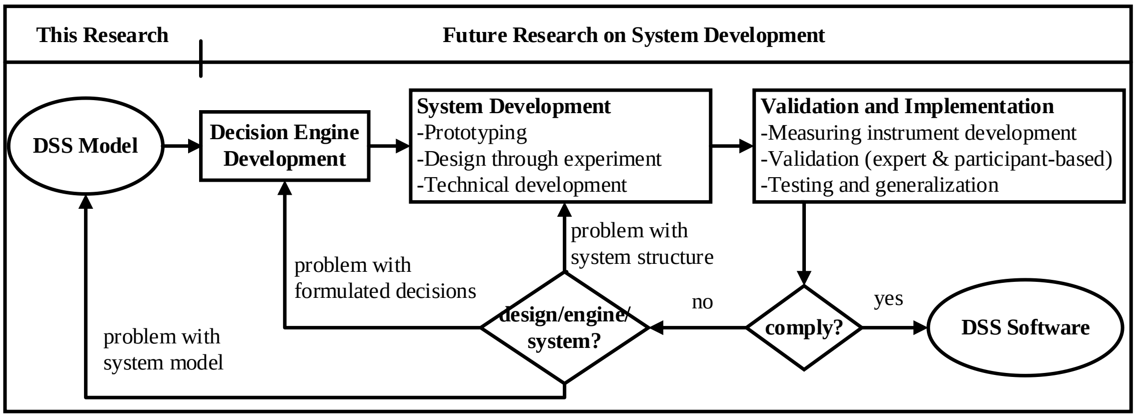
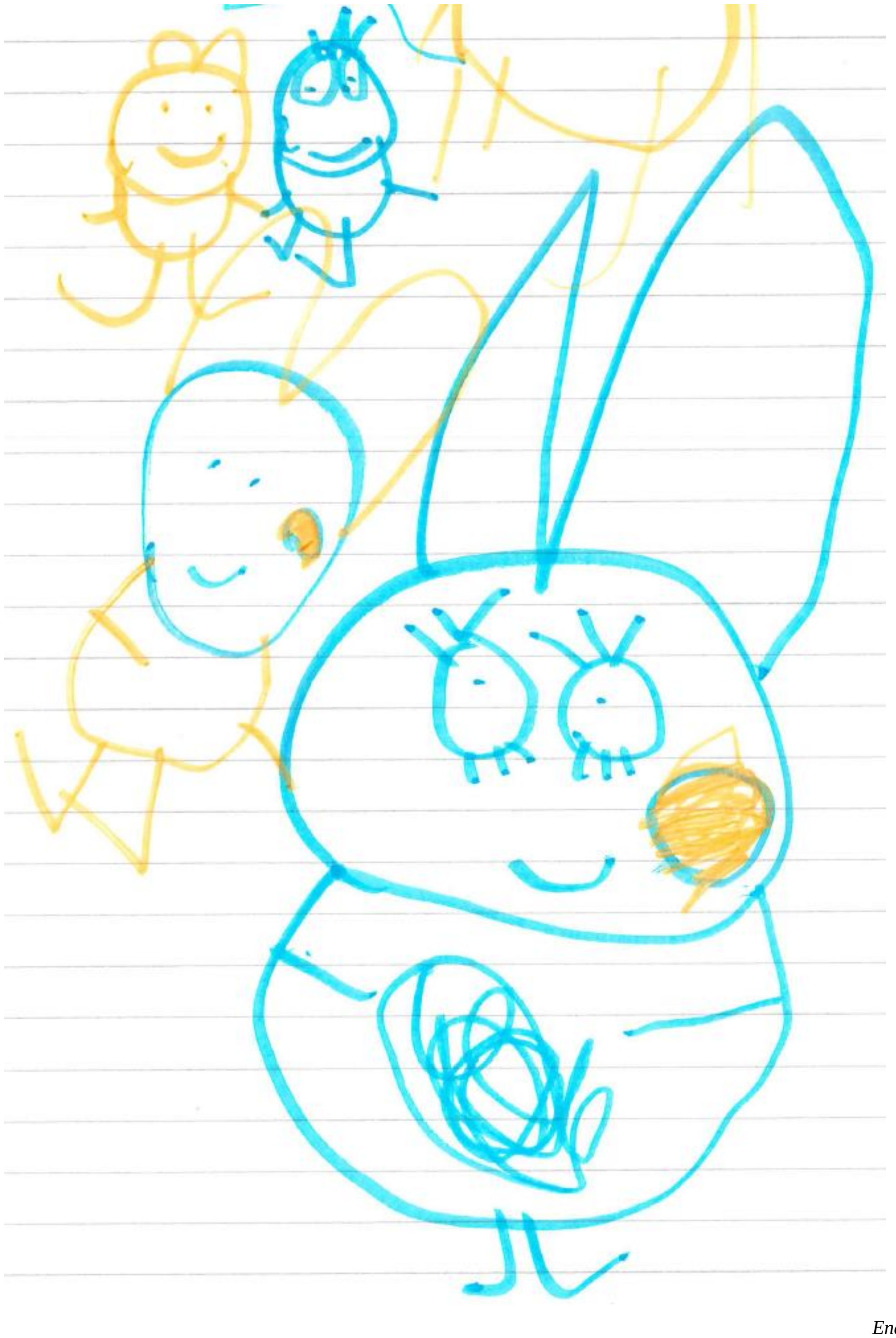


Figure 8.1: Future research directions for humanitarian DSS development



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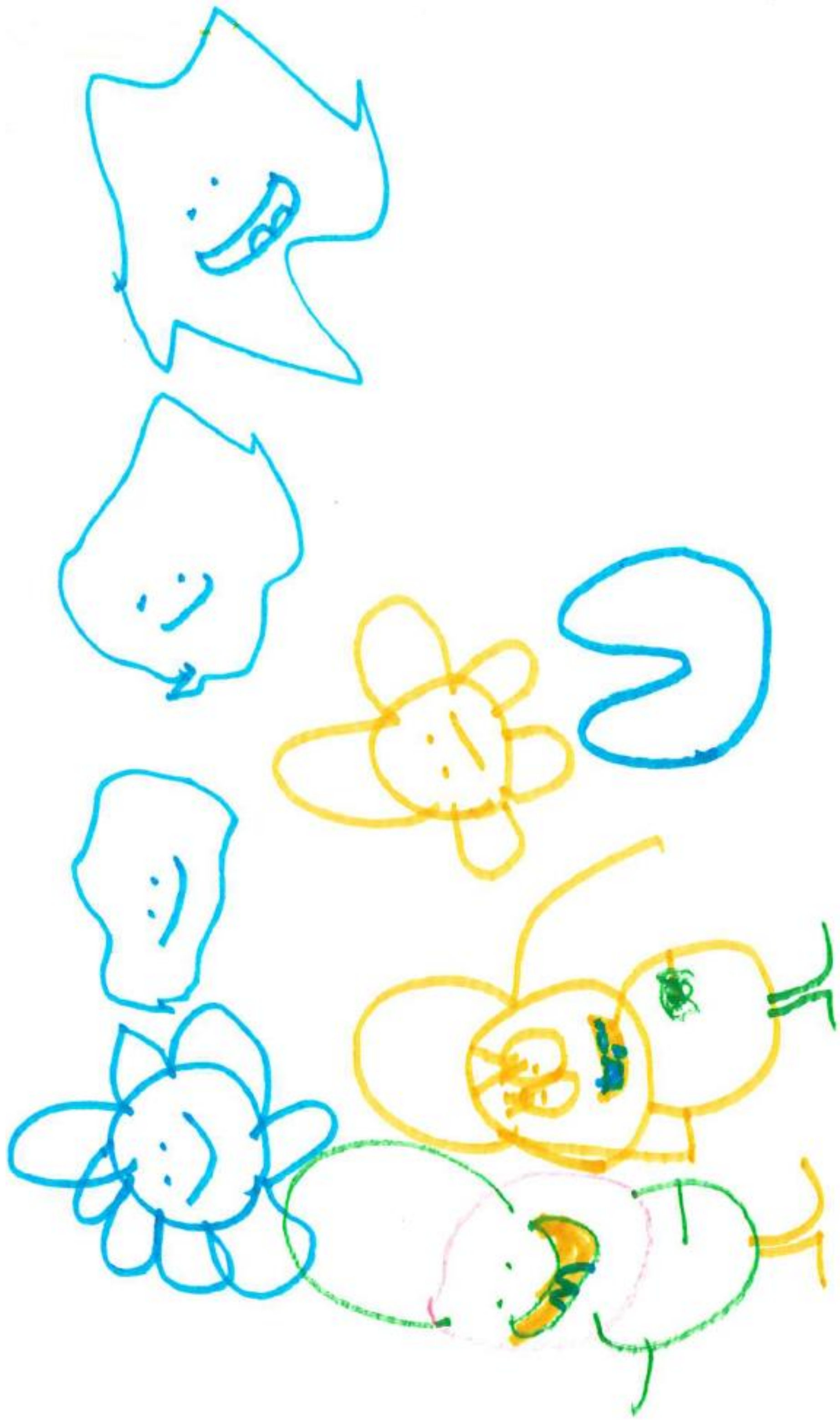

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Appendices

Appendix A: The Concept Matrix

Appendix B: The Morphological Matrix

Appendix C: The Morphological Box

Appendix D: The Identified Problem Areas and Decision Factors

Appendix E: The Panelists’ Profiles

Appendix F: The Survey Questionnaires

Appendix G: Research Publications

Appendix A: The Concept Matrix

The concept matrix represents how the selected literature was coded to identify different concepts related to the inquiry. Here, I present a sample view of the large concept matrix generated in this study.

ID	General Paper information A-Author J/C-Journal/Conference PY-Publication Year UC-University Country				Disaster type N-Natural MM-Man Made SlO-Slow Onset SuO-Sudden Onset				Disaster lifecycle stage M-Mitigation P-Preparedness Res-Response Rec-Recovery				Research Method LR-Literature Review CS: Case Study/Scenario Sur-Survey Int-Interview FW-Framework App/Sys-Application/System							
	A	J/C	PY	UC	N	MM	SlO	SuO	M	P	Res	Rec	LR	CS	Sur	Int	Model/ Method	Demo /FW	Concept/ Pure LR	App/Sys
1	Holguin+4	JOM	2012	USA	X						X			X		X		FW	X	
2	Liberatore +4	J-CAOR	2014	Spain, UK	X						X		X	X			X			
3	Sheu+1	J-TRB	2014	Taiwan	X						X		X				X	D		
4	Gralla+2	POMS	2014	USA	Not specified						X				X		X			
5	Zhen+2	IEEE	2015	China, Singapore	X	X					X						X	D		

ID	Problem type DM-Decision Making DP-Distribution Planning FL-Facility Location DC-Distribution Centers NF-Network Flow TP-Transportation planning						Geography	Optimization type D-Deterministic S-Stochastic		Decision level S-Strategic T-Tactical O-Operational			Stakeholders L/I-Local/International NGO-Non-Governmental Organization Govt-Government Mili-Military ER-Emergency Responders (disaster administrators/practitioner) HL- Humanitarian Logistician R- Researcher						Coordination Decen-Decentralized Cen-Centralized		Objectives Et-Effective Ee-Efficiency Ey-Equity			Constraints
	DM	DP	FL	IM	NF	DC	Places considered	D	S	S	T	O	L/I	NGO	Govt	Mili	ER/ HL	R	Decen	Cen	Et	Ee	Ey	Separately maintained
1	X								X	X							X		Limited in post-disaster		X	X		1.5
2		X			X		Haiti		X			X	Investing Agency for recovery, decision-maker				X				X	X	X	2.6
3	X	X					Linbian & Jiadong, Taiwan		X	X							X			X	X	X		3.5
4	X	X						Not specified		x							X				X	X	X	4.7
5	X		X		X		Shanghai, China	X		X							X				X	X		5.5

Appendix B: The Morphological Matrix

The morphological matrix presents the concept-centric analysis of the mapping between problem areas and their associated decision factors (Objectives, Variables, and Constraints). By accommodating Paper IDs, the matrix maintains a link with the Concept matrix presented in Appendix A.

List of finally reviewed articles

Paper ID	**References (Objectives category)**	**Paper ID**	**References (Constraints category)**
1	Barbarosoglu and Arda, 2004	**15**	Liberatore et al., 2014
2	OPricovic and Tzeng, 2002	**16**	Sheu and Pan, 2014
3	Chang et al., 2007	**17**	Gralla et al., 2014
4	Kristianto et al., 2014	**18**	Han et al., 2010
5	Nagurney et al, 2011	**19**	Rawls and Turnquist, 2010
6	Rolland et al., 2011	**20**	Rottkemper and Fischer, 2013
7	Rottkemper et al., 2011	**21**	Ransikarbum and Mason, 2016
8	Tofighi et al., 2016	**22**	Rancourt et al., 2014
9	Zhen et al., 2015	**23**	Barahona et al., 2013
10	Blecken et al., 2011	**24**	Chunguang et al., 2010
11	Ransikarbum and Mason, 2014	**25**	Cao et al., 2016
12	Moreno et al., 2016	**26**	Jabbarzadeh et al., 2016
13	Fereiduni and Shahanaghi, 2017	**27**	Fahimnia et al., 2017
14	Hu et al., 2017	**28**	Nagurney and Nagurney, 2016
	…..	**29**	Habib and Sarkar, 2017
		30	Jha et al., 2017

The Morphological Matrix for Decision Objectives

Paper ID	Problem Areas	Decision-making Objectives								
		Cost (min.) **	distance (min.)	time (min.)***	Coverage (max.)	transportation quantity (max.) & curve degree (min.)	repeat parameter (min.)	flow quantity burden (min.)	customer satisfaction (max.)	number of distribution center (min.)
1, 4, 12	Transportation	t		tt						
3	Emergency Logistics Planning	a	x							
4, 7, 10, 13, 19	Inventory Allocation & relocation	x								
5, 9, 16, 27, 28	Supply Chain Network design	t, o, p*	x	dt						
6, 18	Scheduling	x	x							
8, 12, 13, 18, 25, 26, 30	Facility Location	o, t	x		x				x	
8, 11, 20, 22, 23	Relief Distribution & re-distribution	r, t		x	x					x
14	Supplier selection	t								
15	Distribution network recovery planning		x		x					
23	Inventory stocking				x					
24	Distribution route selection					x	x	x		
29	Temporary Disaster Debris Management Site selection	t								
30	Evacuation camp selection	t							x	

*Penalty cost includes psychological cost, deprivation cost and resource cost.
**Cost: t:total, a:average, p:penalty, o:operating
***Time: tt:travel time, dt:distribution time

The Morphological Matrix for Decision Variables

Paper ID	**Problem Areas**	**Decision Variables**													
		transportation cost	inventory cost	penalty cost	set-up cost	operational cost	inventory holding cost	fixed (f) & variable cost	replenishment cost	procurement cost	equipment cost	demand meet (m) / meeting cost (c)	beneficiaries access cost	backlogging cost	labor (l) / stay cost (c)
1, 4, 12	Transportation	X	X	d				X							
3	Emergency Logistics Planning		X		X						X				
4, 7, 10, 13, 19	Inventory Allocation & relocation	X	X	r	X	X	X	X	X						
5, 9, 16, 27, 28	Supply Chain Network design	X		X	X	X	X	f							l
6, 18	Scheduling			d											
8, 12, 13, 18, 25, 26, 30	Facility Location	X	X	r	X	X		f		X		c			
8, 11, 20, 22, 23	Relief Distribution & redistribution	X		r	X	X						m	X		
14	Supplier selection	X	X	r				f		X					
15	Distribution network recovery planning														
23	Inventory stocking													X	
24	Distribution route selection														

Paper ID	Problem Areas	Decision Variables													
		transportation cost	inventory cost	penalty cost	set-up cost	operational cost	inventory holding cost	fixed (f) & variable cost	replenishment cost	procurement cost	equipment cost	demand meet (m) / meeting cost (c)	beneficiaries access cost	backlogging cost	labor (l) / stay cost (c)
29	Temporary Disaster Debris Management Site selection	X													
30	Evacuation camp selection	X		X	X										s

Paper ID	Problem Areas	Decision Variables (continues)											
		set-up time	distribution time	demand time	travel time	inventory flow (f) /capacity	transport mode shift (m) /supply unit (s)	Emer. area grouping & levelling	salvage value	transportation quantity	risk penalty	travel distance	resource mis (m)/pre-allocation (p) /need (n)
1, 4, 12	Transportation					f	m						
3	Emergency Logistics Planning							X					
4, 7, 10, 13, 19	Inventory Allocation & relocation					X							
5, 9, 16, 27, 28	Supply Chain Network design			X								X	
6, 18	Scheduling	X			X	f						X	m
8, 12, 13, 18, 25, 26, 30	Facility Location				X	X					X	X	p,n

Paper ID	Problem Areas	Decision Variables (continues)												
		set-up time	distribution time	demand time	travel time	inventory flow (f) /capacity	transport mode shift (m) /supply unit (s)	Emer. area grouping & levelling	salvage value	transportation quantity	risk penalty	travel distance	resource mis (m)/pre-allocation (p) /need (n)
8, 11, 20, 22, 23	Relief Distribution & redistribution		X	X	X	X	s						n
14	Supplier selection								X				
15	Distribution network recovery planning												
23	Inventory stocking												
24	Distribution route selection									X		X	
29	Temporary Disaster Debris Management Site selection									X			
30	Evacuation camp selection										X		

The Morphological Matrix for Decision Constraints

Paper ID	Problem Areas	Decision Constraints											
		capacity*	inventory flow	mode shift control	availability/allocation of resources	demand satisfaction	excess & shortage of demand	rescue centers	equipment rental cost	transportation**	shortage & surplus equipment	task completion sequence	item types
1, 4, 12	Transportation	tr	X	X	X	X	X			t, u			
3	Emergency Logistics Planning	sh						X	X	c	X		
4, 7, 10, 13, 19	Inventory Allocation & relocation	tr, r, sh	X	X	X	X				u			
5, 9, 16, 27, 28	Supply Chain Network design	sh	X		X	X							
6, 18	Scheduling	rt,r	X		X	X						X	
8, 12, 13, 18, 25, 26, 30	Facility Location	c, sh, r, p	X			X							X
8, 11, 20, 22, 23	Relief Distribution & redistribution	sh, r			X	X				c			
14	Supplier selection	p	X		X								
15	Distribution network recovery planning					X							
23	Inventory stocking	sh	X										
24	Distribution route selection												
29	Temporary Disaster Debris Management Site selection	sh											
30	Evacuation camp selection	c				X							

Paper ID	**Problem Areas**	**Decision Constraints (continue)**								
		number of storehouses	budget	target time	trip & travel time	load flow	operational cost	replenishment cost	inventory holding cost	routes' length and number
1, 4, 12	Transportation				X					
3	Emergency Logistics Planning									
4, 7, 10, 13, 19	Inventory Allocation & relocation	X								
5, 9, 16, 27, 28	Supply Chain Network design	X		X						
6, 18	Scheduling	X				X				
8, 12, 13, 18, 25, 26, 30	Facility Location	X	X			X				X
8, 11, 20, 22, 23	Relief Distribution & redistribution	X	X				X	X	X	
14	Supplier selection									
15	Distribution network recovery planning					X				
23	Inventory stocking									
24	Distribution route selection									X
29	Temporary Disaster Debris Management Site selection					X				
30	Evacuation camp selection									X

*capacity: tr:transport, sh:storehouse, rt:response team, c:center, r:road, p:supplier's production **transportation: c:cost, u:uint, t:type, d:distance

Appendix C: The Morphological Box

The morphological boxes are formed by merging the conceptually similar problem areas that encompass identical decision factors (Objectives, Variables, and Constraints). Thus, the total number of problem areas was reduced to six from 13 problem areas listed in Appendix B.

The Morphological Box for Decision Objectives

Problem Areas	**Decision-making Objective**							
	minimization						**maximization**	
Transportation	total cost	travel time						
Inventory Management	total, penalty cost							
Relief Supply Chain	total, average, operational, psychological cost		travel distance	distribution time				
Facility Location	total, operational cost		travel distance				coverage	customer satisfaction
Humanitarian Relief Distribution	total, resource penalty cost	travel time	travel distance	distribution time	curve degree, flow quantity & repeat parameters	number of distribution centers	coverage	transportation quantity
Scheduling	total, penalty cost		travel distance					

The Morphological Box for Decision Variables

Problem Areas	Decision Variables							
	penalty cost	transportation cost	inventory cost	fixed & variable cost	operational cost	set-up cost	inventory flow & capacity	travel distance
Transportation	deprivation cost	x	x	x			inventory flow	
Inventory Management	resource cost	x	x	x	x	x	x	
Relief Supply Chain	psychology, deprivation, resource cost	x	x	fixed cost	x	x		x
Facility Location	psychology, deprivation, resource cost, backlogging cost	x	x	fixed cost	x	x	x	x
Humanitarian Relief Distribution	resource cost	x			x	x	x	x
Scheduling	deprivation cost						inventory flow	x

Problem Areas	Decision Variables (continue)						
	others						
Transportation					transport mode		
Inventory Management	replenishment cost	inventory holding cost					
Relief Supply Chain	labor cost	inventory holding cost	demand time	salvage value	equipment cost	procurement cost	emergency areas grouping and levelling
Facility Location	demand meeting cost	stay cost @ camp	risk penalty	travel time	transportation quantity	procurement cost	resource need and pre-allocation

Problem Areas	Decision Variables (continue)							
Humanitarian Relief Distribution	supply unit	beneficiaries access cost	demand time	travel time	transportation quantity	distribution time	resource need (demand meeting)
Scheduling			set-up time	travel time			resource misallocation

The Morphological Box for Decision Constraints

Problem Areas	Decision Constraints									
	capacity	inventory flow	number of storehouses	resource availability	demand satisfaction	others				
Transportation	transport	x		x	x	transport mode shift control		transport type and unit	excess & shortage of demand	trip & travel time
Inventory Management	transport, storehouse, road	x	x	x	x	transport mode shift control		transport unit		
Relief Supply Chain	storehouse, suppliers' production	x	x	x	x	equipment rental cost	rescue centers	transport cost	shortage & surplus equipment	target time
Facility Location	center, storehouse, road, suppliers' production	x	x	budget	x	item types	load flow			routes' length and number
Humanitarian Relief Distribution	storehouse, road	inventory holding cost	x	budget & resource availability	x	replenishment cost	load flow	transport cost	travel distance	operational cost
Scheduling	road, response team	x	x	x	x		load flow			task completion sequence

Appendix D: The Identified Problem Areas and Decision Factors

Decision Factors			Decision Problem Areas (DPAs)						Total Attrib-utes
			HRD	**FL**	**RSC**	**IM**	**Transp**	**Sched**	6
Decision Objectives (O)	**Max**	cov	x	x					14
		others	tranqua	bensa					
	Min	trat	x				x		
		costs	penco,resco, toco	opco,toco	aco,opco,psyco,toco	penco,toco	toco	penco,toco	
		disti	x		x				
		tradi	x	x	x			x	
		others	numdic						
			pler						
Decision Variables (V)		tradi	x	x	x			x	28
		infloc	x	x		x	inflo	inflo	
		sec	x	x	x	x			
		opco	x	x	x	x			
		fivac		fic	fic	x	x		
		inc		x	x	x	x		
		tranco	x	x	x	x	x		
		penco	resco	depco,psyco,resco	baco,depco, psyco,resco	resco	depco	depco	
		rene	x	x					
		proc		x	x				
		tran-qua	x	x					
		trat	x	x				x	
		det	x		x				
		inhoc			x	x			
		others	disti	ripe	eagl	repco	tram	seti	
			bac	stacoca	eco			resmi	
			sun	demco	salva				
					lac				
Decision Constraints (C)		desa	x	x	x	x	x	x	21
		rea	bua,rea	bua	x	x	x	x	
		nus	x	x	x	x		x	
		inflo	inhoc	x	x	x	x	x	
		cap	roc,stoc	cenca,roc,stoc, supca	stoc,supca	roc,stoc,tracap	tracap	roc,retca	
		tranco	x		x				
		tratu				tranu	x		
		lof	x	x				x	
		tra-moshic				x	x		
		others	opco	rolen	tati		ttt	tacos	
			tradi	it	shose		eshod		
			repco		rec				
					erenco				

List of abbreviations (alphabetically sorted)
[a]ccess [co]st, [ba]cklogging [co]st, [b]eneficiaries [a]ccess [c]ost, [ben]eficiary [sa]tisfaction, [bu]dget [a]vailability, [cap]acity, [cen]ter's [ca]pacity, [cov]erage, [de]mand [m]eeting [co]st, [de]mand [sa]tisfaction, [de]mand [t]ime, [dep]rivation [co]st, [dis]tribution [ti]me, [e]mergency [a]reas [g]rouping and [l]evelling, [e]quipment [co]st, [e]quipment [ren]tal [co]st, [e]xcess & [sho]rtage of [d]emand, [F]acility [L]ocations, [fi]xed [c]ost, [fi]xed & [va]riable [c]ost, [in]ventory [c]ost, [in]ventory [flo]w, [in]ventory [flo]w & [c]apacity, [in]ventory [ho]lding [c]ost, [I]nventory [M]anagement, [i]tem [t]ypes, [la]bor [c]ost, [lo]ad [f]low, [num]ber of [di]stribution [c]enters, [nu]mber of [s]torehouses, [op]erational [co]st, [pen]alty [co]st, [p]ractical [l]ength of [e]mergency [r]oute, [pro]curement [c]ost, [psy]chological [co]st, [R]elief [D]istribution, [R]elief [S]upply [C]hain, [rep]lenishment [co]st, [re]scue [c]enters, [re]sponse [t]eams' [ca]pacity, [re]source [a]vailability, [res]ource [co]st, [res]ource [mi]sallocation, [re]source [ne]ed, [ri]sk [pe]nalty, [ro]ad [c]apacity, [ro]utes' [le]ngth & [n]umber, [sal]vage [va]lue, [Sched]uling, [se]t-up [c]ost, [se]t-up [ti]me, [sho]rtage & [s]urplus [e]quipment, [sta]y [co]st @ [ca]mp, [sto]rehouse [c]apacity, [su]ppliers' [p]roduction [ca]pacity, [s]upply [un]it, [ta]rget [ti]me, [ta]sk [co]mpletion [s]equence, [to]tal [co]st, [Transp]ortation, [tra]nsport [cap]acity, [tran]sport [co]st, [tra]nsport [m]ode, [tra]nsport [mo]de [shi]ft [c]ontrol, [tran]sport [qua]ntity, [tra]nsport [t]ype & [u]nit, [tran]sport [u]nit, [tra]vel [di]stance, [tra]vel [t]ime, [t]rip & [t]ravel [t]ime.

Appendix E: The Panelists' Profiles

SL	PID	MPI	Affiliated Organization(s) and Country	Summary of major contributed disasters	Found through
1	**P2**	**Q''**	Logistics Cluster Coordination, World Food Program, Nepal	Earthquake in Eastern Nepal 1988, Haiti 2010, Gorkha 2015 and several other disasters	Nepal Police
2	**P3**	**Q''**	Nepali Army Crisis Management Centre, Nepal	Earthquake in Gorkha 2015 and several other disasters	
3	**P6**	**Q'**	Papua University, Indonesia (consult on disasters)	Disaster Risk Reduction in West Papua and several other disasters	CIEM Lab
4	**P8**	**Q''**	Universitas Pembangunan Nasional Veteran Yogyakarta, Indonesia (consult on disasters)	Merapi and Kelud volcanic disasters	
5	**P12**	**Q''**	Yayasan Dompet Dhuafa Republika, Indonesia	Earthquake in Lombok 2018, Central Sulawesi 2018 and several other disasters	Personal contact
6	**P19**	**Q''**	Logistics Cluster Coordination, World Food Program, Thailand	Earthquake in Haiti 2010, Indonesia 2018 and several other disasters	Web search
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 (consult on disasters)	Earthquake in Gorkha 2015 **(Skype: 26 minutes)**	Colleagues
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, USA	Earthquake in Northridge 1992 and several other disasters	
12	**P39**	**Q'**	NetHope, Havard Humanitarian Initiative Center for Humanitarian Data, Northwestern University, USA (consult on disasters)	Earthquake in Haiti and Nepal and several other disasters	
13	**P40**	**I'**	WeRobotics, Switzerland (consult on disasters)	Nearly every major humanitarian emergency for the past 15 years **(Skype: 60 minutes)**	
14	**P41**	**Q''**	Standby Task Force, USA	Earthquake in Nepal and several other disasters	

SL	PID	MPI	Affiliated Organization(s) and Country	Summary of major contributed disasters	Found through
15	**P42**	**I'**	TU Delft, Tilburg University, and consultant for some NGOs and Civil Protection organizations, The Netherlands (consult on disasters)	Earthquake in Haiti 2010, Philippines 2013, Nepal 2015, Indonesia 2018 and several other disasters **(Skype: 50 minutes)**	
16	**P44**	**Q''**	UNOCHA, UN Human Rights, UNDAC, Switzerland	Sudan 2004, Niger 2005, Lebanon 2006, Typhoon Haiyan 2013	
17	**P52**	**Q'**	Perkumpulan Lingkar, Indonesia	Earthquake in Jogja 2006	Personal contact
18	**P57**	**I'**	National disaster mitigation agency (BNPB) & Mohammodia disaster management, Indonesia	Earthquake in Jogja 2006, Selat Sunda, Sulawesi and Lombok 2018 **(Skype: 32 minutes)**	
19	**P58**	**Q''**	World Food Program, Nepal	August 2017 Floods	P2
20	**P63**	**I''**	Federal University of Rio de Janeiro, Brazil (consult on disasters)	Several humanitarian fieldworks **(Face-to-face: 95 minutes & 90 minutes)**	Personal contact
21	**P68**	**Q''**	Caritas Germany, Indonesia	Earthquake, Tsunami and Flash Flood	P52
22	**P69**	**Q''**	WALHI Yogyakarta, SHEEP Indonesia, National WALHI, Sulteng Bergerak, Selat Sunda Bergerak, 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 **(WhatsApp: 46 minutes)**	

Abbreviations: PID- anonymized participant ID, **MPI**- the medium of provided information, **Q'**- questionnaire 1, **Q''**- questionnaire 1 & 2, **I'**- guided interview, **I''**- open-ended interview

Appendix F: The Survey Questionnaires

1. The Questionnaire for the Survey Round 1

2. The Questionnaire for the Survey Round 2

The Questionnaire for the Survey Round 1

UNIVERSITY OF AGDER
Mohammad Tafiqur Rahman (tafiqur.rahman@uia.no)
University of Agder, Kristiansand, Norway
Please reply by December 25, 2018

Welcome to the Survey

Motivation

To respond to disasters in a chaotic environment, practitioners conduct complex and challenging tasks. While making decisions on **relief distribution (RD)**, they face uncertainty in identifying appropriate decision factors (**decision objectives, variables, and constraints**). To assist them, we have developed a decision-making framework in this research. The framework consists of a list of decision aspects that need to be empirically tested and evaluated for developing a practice-oriented RD process model in the next step.

We seek the opinions of expert practitioners in humanitarian logistics (HL). **You are one of those experts** who has practical experiences in HL operations; that is why we are approaching you. We would also be interested in checking how each of the decision aspects in RD decision problem type (DPT) influences other DPTs: **facility locations, relief supply chain, inventory management, transportation,** and **scheduling**. Decision factors and DPTs are defined in the following table.

<table>
<tr><th>Decision Dimension</th><th colspan="2">Description</th></tr>
<tr><td>Decision Objectives</td><td colspan="2">Aim to make efficient and effective decisions for distributing relief to affected people in a disaster area.</td></tr>
<tr><td>Decision Variables</td><td colspan="2">Decision-making aspects that are controlled by the decision-makers.</td></tr>
<tr><td>Decision Constraints</td><td colspan="2">Decision-making aspects that define limitations on decisions and are not directly controlled by the decision-makers. However, decision variables must satisfy these constraints to produce feasible solutions to decision-making problems.</td></tr>
<tr><td rowspan="7">Decision Problem Types</td><td colspan="2">Logistical decisions that commonly influence last-mile relief distribution.</td></tr>
<tr><td>1. Relief Distribution</td><td>To quickly and efficiently distribute relief materials to the affected population.</td></tr>
<tr><td>2. Facility Locations</td><td>Identifying the most suitable places for relief materials to be stored in the relief network.</td></tr>
<tr><td>3. Relief Supply Chain</td><td>The most dynamic and agile supply chains to maintain the flow of relief materials and services to demand points.</td></tr>
<tr><td>4. Inventory Mgt.</td><td>Efficiently manage the inflow and outflow of relief materials</td></tr>
<tr><td>5. Transportation</td><td>Transport relief materials to the demand points.</td></tr>
<tr><td>6. Scheduling</td><td>Schedule relief items, transport, and logistic support to the demand points.</td></tr>
</table>

UNIVERSITY OF AGDER

Please reply by December 25, 2018

Instruction to answer the questionnaire (Section B-D):

1. Please make yourself familiar with the **decision-making dimensions** tabulated on the previous page.
2. Please **rank the importance** of each attribute in the relief distribution process on a scale of 1 to 6.
1: Not important and **6:** Very important
3. If an individual relief distribution decision-making aspect is also **applied** to other decision problem types (DPT), check the respective cell **with an 'X' mark**. Other decision DPTs are: Facility Location, Relief Supply Chain, Inventory Management, Transportation, and Scheduling.
4. We highly encourage you to **provide a brief explanation** of your ranking in the fourth column, though it is kept optional for your flexibility.
5. In the last row, please **state** missing aspects that you practically experienced and think should be listed. If possible, please provide a brief description of them and mention their influences on other DPTs.

Thank you very much for your valuable participation!

Section A

Please tell us about **your expertise** and provide us with **your consent** to use your data in this research.

Your Affiliated Organization(s) & its Web Address(es)	
Your working background (in brief)	
Major relief operations you have been involved in	
Your role in the participated humanitarian logistics operations	
Your consent on data processing	I give consent for my personal data to be processed in this research – ***(Yes/No)***, please keep the desired option by omitting the other.
End of Section A. Please save your replies.	

Please reply by December 25, 2018

Section B

Ranking of decision-making Objectives for efficient and effective relief distribution.

Serial	Decision aspects in Relief Distribution problem type	Please Rank 1 to 6 (1: Not important 6: Very important)	Please briefly explain your answer	Is this decision aspect applicable to other decision problem types along with Relief Distribution? (Please set 'X' if Yes)				
				Facility Location	Relief Supply Chain	Inventory Mgt.	Transportation	Scheduling
1	Serve maximum relief demands							
2	Dispatch maximum relief per transport trip							
3	Minimize travel time to deliver relief items to the points of distribution							
4	Minimize relief distribution time							
5	Minimize travel distance to distribute relief							
6	Minimize total cost to operate the entire RD process							
7	Minimize resource procurement cost							
8	Minimize unused inventories and weighted shortage cost							
9	Minimize number of DC to cover all beneficiaries							
10	Selection of optimal relief distribution route to transport maximum quantity							
Addition	**Please suggest any other aspect(s) that you believe is related to RD. Please also mention whether they apply to other decision problem types. Please provide a brief explanation.**							
End of Section B. Please save your replies.								

Section C

Ranking of relief distribution decision-making Variables that are controlled by the decision makers.

Serial	Decision aspects in Relief Distribution problem type	Please Rank 1 to 6 (1: Not important 6: Very important)	Please briefly explain your answer	Is this decision aspect applicable to other decision problem types along with Relief Distribution? (Please set 'X' if Yes) Facility Location	Relief Supply Chain	Inventory Mgt.	Transportation	Scheduling
1	To be distributed, total distance relief items need to travel							
2	Storing capacity and amount of commodity flow towards distribution centers							
3	Cost for unused relief items or unmet (un)certain needs							
4	Fixed and variable cost to transport relief items to the demand points							
5	Operational cost of supplying relief items (e.g., linking network cost, distribution centers' management and hand-out costs)							
6	Cost for setting up new or disrupted distribution centers							
7	Number of distribution centers to cover all beneficiaries							
8	Total access cost of beneficiaries to travel and collect relief items							
9	Transportation quantity to meet flow quantity burden of distribution route							
10	Time, when a demand was or would be urged							
11	Time taken to travel towards distribution points (based on, e.g., route selected, distance, resource allocated)							
12	Time taken to distribute necessary and available relief items (based on allocated resources)							
13	Demanded and prioritized relief items at demand points							

Serial	Decision aspects in Relief Distribution problem type	Please Rank 1 to 6	Please briefly explain your answer	Is this decision aspect applicable to other decision problem types along with Relief Distribution? (Please set 'X' if Yes)				
		1: Not important 6: Very important		Facility Location	Relief Supply Chain	Inventory Mgt.	Transportation	Scheduling
Addition	Please suggest any other aspect(s) that you believe is related to RD. Please also mention whether they apply to other decision problem types. Please provide a brief explanation.							
End of Section C. Please save your replies.								

Section D

Ranking of relief distribution decision-making Constraints that are not controlled by the decision makers.

Serial	Decision aspects in Relief Distribution problem type	Please Rank 1 to 6 (1: Not important 6: Very important)	Please briefly explain your answer	Is this decision aspect applicable to other decision problem types along with Relief Distribution? (Please set 'X' if Yes) Facility Location	Relief Supply Chain	Inventory Mgt.	Transportation	Scheduling
1	Capacity of central, regional, or local stor-ages							
2	Number of vehicles to traverse at selected routes (e.g., capacity of serving vehicles by volume and weight)							
3	Cost for holding surplus or undeliv-ered/undistributed relief items							
4	Required number of central, regional, or local storehouses to support all demand points							
5	Available budget to keep the distribution network active (e.g., budget for relief trans-portation or restora-tion of centers)							
6	Level of meeting hu-manitarian needs							
7	Overstocking (of relief items) cost in global and central depots							
8	Quantity of relief items to be delivered or sup-plied							
9	Cost to transport relief items between central and other depots							
10	Practical length of emergency route							
11	Variable and fixed transshipment costs between regional de-pots							
12	Available relief items to be delivered and dis-tributed							
Addition	**Please suggest any other aspect(s) that you believe is related to RD. Please also mention whether they apply to other decision problem types. Please provide a brief explanation.**							

Serial	Decision aspects in Relief Distribution problem type	Please Rank 1 to 6	Please briefly explain your answer	Is this decision aspect applicable to other decision problem types along with Relief Distribution? (Please set 'X' if Yes)				
		1: Not important 6: Very important		Facility Location	Relief Supply Chain	Inventory Mgt.	Transportation	Scheduling
End of Section D. Please save your replies.								

The survey ends here. Thanks a lot for your participation.

Please proceed to the next page for "Non-Disclosure Agreement".

Non-Disclosure Agreement

This is the end of this round of the survey. You are an important respondent to this qualitative questionnaire, and your answers will represent a valuable contribution to the research. Your participation could lead to joint research ventures on various scopes of humanitarian logistics in the future. We highly appreciate your cooperation and contribution. Your data in each round of this survey will be protected by the primary contact and be anonymized for use in the research. No circulation or sharing will take place without your consent.

Thanking You once again,

Mohammad Tafiqur Rahman (Primary contact)
Ph.D. Research Fellow
tafiqur.rahman@uia.no
&
Dr. Tim A. Majchrzak
Associate Professor

Department of Information Systems
University of Agder
Kristiansand, Norway

The Questionnaire for the Survey Round 2

Mohammad Tafiqur Rahman (tafiqur.rahman@uia.no)
University of Agder, Kristiansand, Norway

Please reply by March 15, 2019

Welcome to the Second Round of the Survey

Thank you very much for your valuable participation in the first round of the survey. In this second round of the survey, we are presenting the result from the first round and would be seeking your response to the newly added attributes from the experts like you. Here, you will know your ratings to different decision factors (decision objectives, variables, and constraints), their average ratings, ranking, and whether they have received votes to be considered in the model (achieving consensus). **You are welcome to change your previous rating for each attribute and requested to rate the new ones.** To distinguish old and new entries, respective portions are shaded with light yellow and light green. We hope you will find it interesting and worth contributing to.

Section A

Ranking of decision-making Objectives for efficient and effective relief distribution.

Serial	Decision aspects in Relief Distribution problem type	Your Previous Rating	Average Rating	Percentage (%) of overall agreement	Percentage (%) of overall disagreement	Overall Ranking	Achieving Consensus	New Rating: 1(lowest) - 6(highest) (if you wish to change the previous one)
1	Serve maximum relief demands		6.7	86.36	13.64	3	Yes	
2	Dispatch maximum relief per transport trip		5.36	77.27	18.18	5	No	
3	Minimize travel time to deliver relief items to the points of distribution		6.89	95.45	4.545	1	Yes	
4	Minimize relief distribution time		6.89	81.82	13.64	2	Yes	
5	Minimize travel distance to distribute relief		4.68	72.73	27.27	7	No	
6	Minimize total cost to operate the entire RD process		4.86	59.09	36.36	6	No	
7	Minimize resource procurement cost		4.52	63.64	36.36	8	No	
8	Minimize unused inventories and weighted shortage cost		4.18	72.73	18.18	10	No	
9	Minimize number of distribution center to cover all beneficiaries		4.34	68.18	22.73	9	No	
10	Selection of optimal relief distribution route to transport maximum quantity		6.57	90.91	4.545	4	Yes es	
11	Minimize central influence financial flow and other decision							
12	Proper (Maximize) operational management in humanitarian relationship model							
13	Proper response plan							

End of Section A. Please save your replies.

Mohammad Tafiqur Rahman (tafiqur.rahman@uia.no)
University of Agder, Kristiansand, Norway
Please reply by March 15, 2019

Section B

Ranking of relief distribution decision-making Variables that are controlled by the decision makers.

Serial	Decision aspects in Relief Distribution problem type	Your Previous Rating	Average Rating	Percentage (%) of overall agreement	Percentage (%) of overall disagreement	Overall Ranking	Achieving Consensus	New Rating: 1(lowest) - 6(highest) (if you wish to change the previous one)
1	To be distributed, total distance relief items need to travel		6.59	68.18	31.82	10	No	
2	Storing capacity and amount of commodity flow towards distribution centers		6.86	81.82	18.18	7	Yes	
3	Cost for unused relief items or unmet (un)certain needs		5.09	59.09	31.82	13	No	
4	Fixed and variable cost to transport relief items to the demand points		5.32	50	45.45	12	No	
5	Operational cost of supplying relief items (e.g., linking network cost, distribution centers' management and handout costs)		5.68	63.64	36.36	9	No	
6	Cost for setting up new or disrupted distribution centers		5.93	72.73	22.73	11	No	
7	Number of distribution centers to cover all beneficiaries		6.75	77.27	18.18	8	Yes	
8	Total access cost of beneficiaries to travel and collect relief items		6.91	72.73	22.73	6	No	
9	Transportation quantity to meet flow quantity burden of distribution route		7.86	90.91	9.091	5	Yes	
10	Time, when a demand was or would be urged		8.43	77.27	18.18	3	Yes	
11	Time taken to travel towards distribution points (based on, e.g., route selected, distance, resource allocated)		8.43	86.36	9.091	2	Yes	
12	Time taken to distribute necessary and available relief items (based on allocated resources)		8.27	86.36	4.545	4	Yes	
13	Demanded and prioritized relief items at demand points		8.86	86.36	9.091	1	Yes	
14	Assessing local sources of supplies							
15	Relief package standardization (heavy, lightweight, etc.)							
16	Duration of response operation							

Serial	Decision aspects in Relief Distribution problem type	Your Previous Rating	Average Rating	Percentage (%) of overall agreement	Percentage (%) of overall disagreement	Overall Ranking	Achieving Consensus	New Rating: 1(lowest) - 6(highest) (if you wish to change the previous one)
17	Understanding and assessing the disaster situation (environment, vulnerabilities, and coping mechanisms)							
18	Need assessment for current and future operations (victims' locations, items' and victims' categorization, prioritization, and quantity, difficulties to make the materials available to them)							
19	Synchronization of need and operation: think of the responding capacity (from warehouse to the field) before deployment							
20	Knowledge acquisition on previous incidents and analysis							
21	Digital communicating devices							
22	Traffic control plan at distribution points							
23	Social capital (support from local leaders, experts or community)							
24	Targeted community's cultural knowledge or understanding							
25	Relief distribution plan sharing with the beneficiaries							
26	Knowledge on neighboring regions; geographical, topography and demography knowledge about the targeted point of distribution							
End of Section B. Please save your replies.								

Please reply by March 15, 2019

Section C

Ranking of relief distribution decision-making Constraints that are not controlled by the decision makers.

Serial	Decision aspects in Relief Distribution problem type	Your Previous Rating	Average Rating	Percentage (%) of overall agreement	Percentage (%) of overall disagreement	Overall Ranking	Achieving Consensus	New Rating: 1(lowest) - 6(highest) (if you wish to change the previous one)
1	Capacity of central, regional, or local storages		7.91	77.27	18.18	2	Yes	
2	Number of vehicles to traverse at selected routes (e.g., capacity of serving vehicles by volume and weight)		7.7	81.82	18.18	4	Yes	
3	Cost for holding surplus or undelivered/undistributed relief items		4.43	50	45.45	11	No	
4	Required number of central, regional, or local storehouses to support all demand points		5.41	68.18	27.27	10	No	
5	Available budget to keep the distribution network active (e.g., budget for relief transportation or restoration of centers)		7.52	86.36	4.545	6	Yes	
6	Level of meeting humanitarian needs		7.86	86.36	4.545	3	Yes	
7	Overstocking (of relief items) cost in global and central depots		3.18	40.91	54.55	12	No	
8	Quantity of relief items to be delivered or supplied		7.16	81.82	13.64	7	Yes	
9	Cost to transport relief items between central and other depots		5.55	68.18	31.82	8	No	
10	Practical length of emergency route		7.59	86.36	9.091	5	Yes	
11	Variable and fixed transshipment costs between regional depots		5.41	59.09	36.36	9	No	
12	Available relief items to be delivered and distributed		8.27	81.82	13.64	1	Yes	
13	Characteristics of disasters							
14	Characteristics of affected areas							
15	Access to the point of distribution							
16	Civil-military relationship							
17	In-country political situations							
18	Safety and security to respondents, relief supply chain, and beneficiaries							

Serial	Decision aspects in Relief Distribution problem type	Your Previous Rating	Average Rating	Percentage (%) of overall agreement	Percentage (%) of overall disagreement	Overall Ranking	Achieving Consensus	New Rating: 1(lowest) - 6(highest) (if you wish to change the previous one)
19	Social and communication infrastructure							
20	Geographical and environ-mental (weather) conditions of the disaster area							
21	Coordinating with other relief distributing groups (big/small)							
22	Trained, committed and tech-nology supported volun-teers/supporting staffs							
End of Section C. Please save your replies.								

Non-Disclosure Agreement

This is the end of this round of the survey. You are an important respondent to this qualitative questionnaire, and your answers will represent a valuable contribution to the research. Your participation could lead to joint research ventures on various scopes of humanitarian logistics in the future. We highly appreciate your cooperation and contribution. Your data in each round of this survey will be protected by the primary contact and be anonymized for use in the research. No circulation or sharing will take place without your consent.

Thanking You once again,

Mohammad Tafiqur Rahman (Primary contact)
Ph.D. Research Fellow
tafiqur.rahman@uia.no
&
Dr. Tim A. Majchrzak
Associate Professor

Department of Information Systems
University of Agder
Kristiansand, Norway

Appendix G: Research Publications

The following publications are included as part of this research project:

Paper 1 Rahman, M. T., Comes, T., and Majchrzak, T. A. (2017). "Understanding decision support in large-scale disasters: challenges in humanitarian logistics distribution" in Dokas, M.I., Saoud, N.B., Dugdale, J., and Diaz, P. (eds.) *Proceedings of the international conference on information systems for crisis response and management in Mediterranean countries*. Xanthi, Cham, Switzerland: Springer, pp.106-121.

DOI:10.1007/978-3-319-67633-3_9

Paper 2 Rahman, M.T., Majchrzak, T.A., and Comes, T. (2019). "Deep uncertainty in humanitarian logistics operations: decision-making challenges in responding to large-scale natural disasters", *International Journal of Emergency Management*, *15*(3), pp.276-297.

DOI: 10.1504/IJEM.2019.10023857

Paper 3 Rahman, M.T. (2018). "Pragmatism in decision support system research: the context of humanitarian relief distribution", *International Journal of Information Systems for Crisis Response and Management*, *10*(3), pp.63-83.

DOI: 10.4018/IJISCRAM.2018070104

Paper 4 Rahman, M.T., Majchrzak, T.A., Comes, T., and Sein, M.K. (submitted 2020). *A conceptual framework to support decision-making in humanitarian relief operations*.

Under review in an international peer-reviewed humanitarian journal

Paper 5 Rahman, M.T., and Majchrzak, T.A. (2020). "Requirements for relief distribution decision support in humanitarian logistics" in A. Siarheyeva et al. (eds.) *Advances in information systems development (ISD 2019): lecture notes in information systems and organisation, 39*, pp.93-112. Cham Switzerland: Springer.

DOI: 10.1007/978-3-030-49644-9_6

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