A roadmap for higher research quality in humanitarian operations: A methodological perspective

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Abstract

Given the substantial costs of natural and man-made disasters (i.e., mortality, morbidity, and financial losses), scholars in operations management and operations research have conducted extensive research in the last decade in a humanitarian setting. A total of 43 studies that reviewed papers on disaster management and humanitarian operation and pointed out the research gaps in this field of study were published from 2006 to 2018. To enhance the rigor and relevance of future studies, this paper focuses on the methodological aspect of studies on humanitarian operations. The study highlights a set of vital items that should be considered when conducting research in a humanitarian setting: including the problem structuring, understanding the contextual factors in a humanitarian setting, acknowledging the uncertainties in humanitarian operations, incorporating uncertainty in the model, enabling technologies in model development and implementation, and selecting appropriate data and research methods. In addition, this study suggests a meta-process for research on humanitarian operations to target a higher level of research quality in this setting. The implications of the study for authors and reviewers of manuscripts and research proposals are discussed in the last section of the paper.

Keywords:

humanitarian operations, operations research, supply chain management, methodology, research quality, review.

1. Introduction

Between 2001 and 2016, natural disasters left nearly 220 million people affected per year and caused US$ 120 billion economic losses on average (EM-DAT, 2017). In the last decade, we witnessed the three top natural disasters of the century, namely, the 2004 Asian tsunami, the 2008 Cyclone Nargis, and the 2010 Haiti earthquake, and they had a joint death toll of more than 500,000. Most natural disasters are cyclical, as can be observed during cyclone, typhoon, and hurricane seasons (with the latest one in 2017 being particularly devastating in the Americas), recurring rainy seasons, snowmelt floods, and earthquake cycles. Aside from natural disasters, the economic and non-economic effects of man-made disasters, such as terrorist threats and conflicts within countries (e.g., the crises in Syria and Yemen), have grown in the last years and have left many people killed, injured, or displaced (Balcik et al., 2016; Çelik, 2016). These situations are the contextual settings for humanitarian operations (HO) research. Nevertheless, HO research is not just limited to applying the traditional methods and theories of operations research (OR)/operations management (OM) to a new setting.

The humanitarian setting differs from a commercial setting in several aspects, which have to be incorporated in theory and in modeling research projects. The first key difference is the objective of disaster management, which is not profit making but saving lives and reducing human suffering (Gupta et al., 2016). The second main difference is that humanitarian organizations operate under high levels of uncertainty with respect to, inter alia, the timing, place, and quantity of demand; availability of international and local supplies and funding, destabilization of infrastructure (e.g., transportation and communication); the number of other organizations responding to the same disaster; and the behavior or reaction of beneficiaries (Liberatore et al., 2013; Hoyos et al., 2015; Burkart et al., 2016; Grass and Fischer, 2016). Interestingly, the context also drives the content of OR/OM research, sets critical operational constraints, and challenges research to overcome these constraints.

The remarkable negative effect of natural and man-made disasters on the lives of many people around the world and the critical role of logistics activities in relief aid have inspired scholars in OR, OM, and supply chain management (SCM) to conduct more research on HO, humanitarian logistics, and SCM in the last decade (Galindo and Batta, 2013; Balcik, 2016). This action coincides with the numerous HO-related special issues that have been published in mainstream OR/OM journals (e.g. *Journal of Operations Management* [Pedraza-Martinez and Van Wassenhove, 2016] and the *European Journal of Operational Research* [Besiou et al., 2018]), the launch of disaster management and HO editorial departments in top-tier journals such as *Production and Operations Management*[1] or *Journal of Operations Management*[2], and the establishment of a new outlet called *Journal of Humanitarian Logistics and Supply Chain Management*[3]. In addition, forums such as POMS Humanitarian Operations and Crisis Management College and the European OR Societies (EURO) Working Group on Humanitarian Logistics[4] provide platforms for exchanging information and best practices to enhance the rigor and practical relevance of HO studies.

Up until May 2018, 43 HO review papers providing insights into the development of the new interdisciplinary field of OM and OR were published. For many HO scholars, the goal of conducting research is not only to publish papers in academic journals but also to motivate practice by providing theoretical insights or offering decision-making tools to practitioners. Therefore, it is important to investigate the processes and techniques used to enhance the rigor and practical usefulness of HO research. In contrast to review papers that provide a topical overview of HO research, in this study, we analyze the methodology of the review papers and we suggest a framework and a set of guidelines to enhance the rigor of the research and the

[1] http://poms.org/2010/06/disaster_management.html
[2] https://www.journals.elsevier.com/journal-of-operations-management/humanitarian-operations
[3] https://www.emeraldinsight.com/journal/jhlscm
[4] https://www.euro-online.org/web/ewg/39/ewg-hope-euro-working-group-on-humanitarian-operations

practical relevance of research projects in a humanitarian setting. The motivation for this study is to provide guidelines, especially for junior researchers entering this new field of study, by stressing the critical items in research projects (i.e., problem identification, data collection, assumptions, hypothesis development, modeling, and data analysis).

In this manuscript, we use *methodology* as a general research strategy that outlines the way in which research is to be undertaken (Howell, 2013). Accordingly, we identify fundamental issues that should be addressed while using any modeling or empirical methods in the context of humanitarian operations. The paper concludes by providing recommendations that aim at enhancing the impact of future research in this area, to the benefit of those affected by disasters and those providing relief.

In this study, we do not provide a detailed review of empirical or modeling methods, which have been rather extensively discussed in prior review papers. This manuscript presents an overview of the methodological items within prior studies and it provides insight into some common critical issues, which must be addressed in any method in a humanitarian setting, partly related to the method's rigor and partly related to the research's relevance. To assist interested readers in obtaining more knowledge about the items within our findings, we provide examples from past review papers and we cite other relevant references.

The paper is organized as follows. First, we review the literature on research quality in Operations Management and Supply Chain Management. Second, we collect and review the contribution of methods in previous HO review papers. Third, we analyze the collected data and suggest a process or roadmap to aim for a higher research quality in HO from a method perspective. Fourth, we conclude the findings and elaborate the study's implications for researchers and reviewers.

2. Literature Review

2.1. Research quality in OM and SCM

Recently, OM research has called for balanced attention to both dimensions of research rigor and relevance (e.g., Schmenner et al., 2009; Van Mieghem, 2013; Toffel, 2016) and for practice-based research considering both dimensions of generality and validity (Gallien and Scheller-Wolf, 2016). Scholars contend that, even though OM and OR are practice oriented, the relevance of most papers published in this field remains doubtful (Choi et al., 2016). "Unrealistic assumptions about the problem context," "made up problems," and "pretending to solve real problems" are the usual voiced criticisms toward OR/OM research. To avoid such criticism, researchers have to consider multiple stakeholders as part of their audience and readers of journals beyond the people who serve as reviewers, such as managers, practitioners, and policy-makers (Schmenner et al., 2009; Simpson et al., 2015). Scholars not only have to aim for novelty and correctness in their studies, but also for valid and relevant knowledge that can assist managers and practitioners in their decision making and problem solving (Tang, 2015). However, OM researchers usually focus on the mathematical modeling and hypothesis testing methods to solve well-defined problems (Choi et al., 2016). Many studies use simple or few objectives or unrealistic assumptions of the real world, and they offer solutions with limited validity in practice (Singhal and Singhal, 2012a; Gallien and Scheller-Wolf, 2016).

Singhal and Singhal (2012a) suggest that scholars should not focus on one phase of modeling or theoretical testing only but pursue all phases of science and use multiple perspectives. Understanding and structuring a problem through exploratory studies; developing theories and models; testing models through simulations, field, and laboratory experiments to examine the model validity; and evaluating their impact are all required to develop knowledge and strengthen OM (Singhal and Singhal, 2012a; Gallien et al., 2015). Moreover, multiple research perspectives can be obtained by examining different parts of a problem, collecting or accessing

different sources of primary and secondary data, applying different methods of data analysis, and using different sources of data. Taking multiple perspectives allows researchers to provide novel insights especially when "the domain of the system being studied is wide, the system has a high level of complexity (interdependence of elements), the rate of endogenous or exogenous change in the system or its environment is high, or the economic presence and impact across multiple organizations of the system or phenomenon being studied is substantial" (Singhal and Singhal, 2012a).

On the basis of Gallien and Scheller-Wolf (2016), we define high-quality research as a process including the following key activities: real problem identification by consulting the literature and engaging with a firm or nonprofit partner, modeling and theorizing the problem based on real data and incorporating realistic assumptions, offering solutions and insights, testing and validating the results, and delivering a clear report and insights.

2.2. Review papers on HO

By May 2018, a total of 43 HO-specific review papers were published in various journals (Figure 1 and Table 1). First, we collected the papers by searching for recent review papers published in the *European Journal of Operations Research* (Galindo and Batta, 2013; Özdamar and Ertem, 2016; Gutjahr and Nolz, 2016), *Production and Operations Management* (Gupta et al., 2016), and the special issue in the journal of *Surveys in Operations Research and Management Science* (Balçık, 2016). Then, we considered all the review papers cited in the gathered papers; we also used Google Scholar to search for other review papers that might not be cited in the recent review papers.

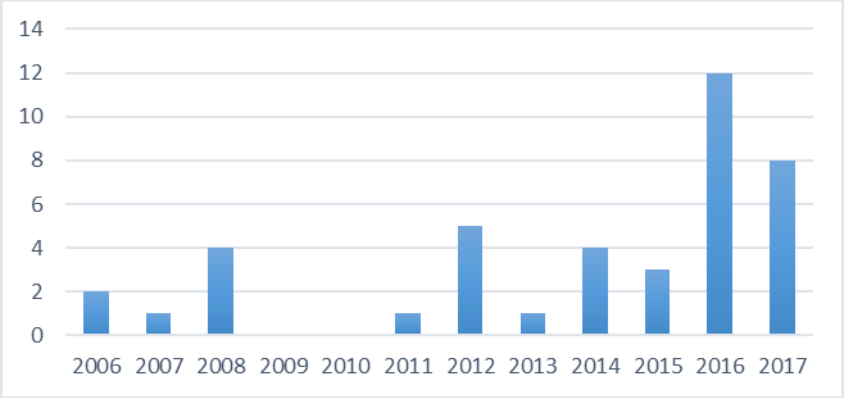

Figure 1. Distribution of review articles on HO according to year

Table 1. List of review papers on disaster operations management

Study	Research focus	Time horizon	# papers reviewed
Abdelgawad and Abdulhai (2009)	Emergency evacuation planning	na	na
Abidi et al. (2014)	Performance management	1970–2012	52
Akter and Wamba (2017)	Big data and disaster management	2010–2017	76
Altay and Green (2006)	OR/MS research on disaster operations management	1980-2004	109
Anaya-Arenas et al. (2014)	Relief distribution networks	1990–2013	83
Balcik et al. (2016)	Inventory management	2006–2016	45
Banomyong et al. (2017)	Humanitarian logistics and humanitarian supply chain performance	2005–2016	52
Bayram (2016)	Optimization models for a large-scale network evacuation	-2016	285*
Bealt and Mansouri (2017)	Community-driven humanitarian logistics	1998–2014	23
Behl and Dutta (2018)	Humanitarian supply chain management	2011–2017	362*
Burkart et al. (2016)	The funding–humanitarian supply chain interface	1997–2016	51
Caunhye et al. (2012)	Optimization models	na	na
Çelik (2016)	Network restoration and recovery	2000–2016	100*
Dasaklis et al. (2012)	Epidemic control and logistics operations	-2011	73
de Oliveira et al. (2016)	Role of private stakeholders	1997–2015	27
Faturechi and Miller-Hooks (2014)	Transportation infrastructure system performance	2000–2013	na
Galindo and Batta (2013)	OR application in disaster management	2005–2010	155
Gizaw and Gumus (2016)	Humanitarian supply chain performance evaluation	2000 –2015	na
Grass and Fischer (2016)	Two-stage stochastic programming	2004–2016	40
Gupta et al. (2016)	Disaster management	1957–2014	268
Gupta et al. (2017)	Big data in humanitarian supply chain management	2005–2016	28
Gutjahr and Nolz (2016)	Multicriteria optimization	-2015	na
Habib et al. (2016)	Mathematical models	2005–2015	94
Hoyos et al. (2015)	OR models with stochastic components	2006–2012	101
Jabbour et al. (2017)	Humanitarian logistics and supply chain management	-2016	87
Jahre (2017)	Supply chain risk mitigations	–2016	na
John et al. (2012)	Humanitarian supply chain management	–2011	na
Kovács and Spens (2007)	Humanitarian logistics	-2006	na
Kunz and Reiner (2012)	Humanitarian logistics	-2011	174
La Torre et al. (2012)	Disaster relief routing	-2010	29
Leiras et al. (2014)	Humanitarian logistics	1980–2012	228
Lettieri et al. (2009)	Disaster management	1980–2005	56
Moshtari and Gonçalves (2017)	Interorganizational collaboration	-2015	28
Natarajarathinam et al. (2009)	Managing supply chains in times of crisis	-2008	118
Nurmala et al. (2017)	Humanitarian–business partnerships	-2016	36
Overstreet et al. (2011)	Humanitarian logistics	-2009	51
Özdamar and Ertem (2016)	Models, solutions, and enabling technologies	-2014	na
Seifert et al. (2018)	Humanitarian SCM related to refugees	1989–2016	53
Simpson and Hancock (2009)	Operational research and emergency response	1965–2007	361
Steigenberger (2016)	Multi-agency coordination	1994–2014	76
Tabaklar et al. (2015)	Theories on humanitarian supply chain management	1995–2014	279
Wright et al. (2006)	OR models and applications in homeland security	- 2006	na
Zheng et al. (2015)	Evolutionary optimization (algorithms)	1996–2014	69

(* refers to studies that include conference proceedings and book chapters in the review process)

Literature reviews are different in several aspects. Some papers are descriptive, highlight the importance of HO and cross-learning from commercial operations, and provide insightful discussions on the critical factors facilitating or inhibiting the efficiency of HO (e.g., Kovács and Spens, 2007). Several studies focus on humanitarian or disaster management in general (e.g., Leiras et al., 2014; Gupta et al., 2016), and others provide in-depth discussions on specific operations. For example, Balcik et al. (2016) review studies on humanitarian inventory planning and management (e.g., papers investigating models on how much, where, and when to stock). Bayram (2016) focuses on studies with optimization models for evacuation planning and management, and Burkart et al. (2016) review the funding–humanitarian supply chain interface. Overall, the review papers analyze the reviewed publications per year and journal outlet, identify trends and gaps in research (e.g., in relation to the types and phases of disasters), and suggest avenues for further research.

Depending on the purpose of the reviews, authors use a set of keywords to collect relevant studies. However, the reviews follow different review protocols (i.e., datasets and journals) and use different time horizons. Galindo and Batta's (2013) study is the only one that follows the protocol applied by a previous study (Altay and Green, 2006) and compares their findings. The review paper by La Torre et al. (2012) stands out because not only does it review previous studies, but it also includes findings from interviews with practitioners to compare the academic and practitioner perspectives in decision-making models developed for the transportation of relief goods.

2.3. Key methodological issues in review papers

Sections in some review papers highlight a number of methodological issues to increase the quality in HO research. In this section, we explain these issues in the following six categories: problem definition and research design, understanding contextual factors, acknowledging the

uncertainties in HO, choosing the appropriate data and research methods, incorporating uncertainty in the research (and in the resultant modelling), and use of enabling technologies for model development and implementation (Table 2).

Table 2. Key items addressed in the review papers

Items	References
1. Problem definition and research design	
• Understanding the problem characteristics • Understanding the real needs of humanitarian organizations • Considering the previous and on-going solutions • Collecting field and real data	(Galindo and Batta, 2013; Anaya-Arenas et al., 2014; Gupta et al., 2016; Pedraza-Martinez and Van Wassenhove, 2016)
2. Understanding contextual factors	
• Different characteristics of each disaster • Different characteristics of each humanitarian organization • HO's decision making structure • Number of actors and their diverse perspectives • Dynamic context	(Altay and Green, 2006; White et al., 2011; La Torre et al., 2012; Gupta et al., 2016)
3. Acknowledging the uncertainties in HO	
• Beneficiaries' needs • Supplied commodities • Funding uncertainty • Limited or damaged infrastructure • Beneficiaries' behavior	(Caunhye et al., 2012; La Torre et al., 2012; Anaya-Arenas et al., 2014; Balcik et al., 2016; Bayram, 2016; Burkart et al., 2016; Gutjahr and Nolz, 2016)
4. Choosing appropriate methods	
• Data • Research methods	(Altay and Green, 2006; Natarajarathinam et al., 2009; White et al., 2011; Kunz et al., 2012; La Torre et al., 2012; Galindo and Batta, 2013; Hoyos et al., 2015; Burkart et al., 2016; Gupta et al., 2016; Gutjahr and Nolz, 2016)
5. Incorporating uncertainty in the modeling	
• Correct assumptions • Objective functions • Integrated models	(Caunhye et al., 2012; La Torre et al., 2012; Galindo and Batta, 2013; Anaya-Arenas et al., 2014; Faturechi and MillerHooks, 2014; Leiras et al., 2014; Hoyos et al., 2015; Özdamar and Ertem, 2015; Balcik et al., 2016; Bayram, 2016; Çelik, 2016; Grass and Fischer, 2016; Gupta et al., 2016; Gutjahr and Nolz, 2016)
6. Use of enabling technologies for model development and implementation	
• Integrating models with information systems • Decision support systems • Suitable solution algorithms • Real-time information updates	(Caunhye et al., 2012; La Torre et al., 2012; Galindo and Batta, 2013; Anaya-Arenas et al., 2014; Özdamar and Ertem, 2015; Balcik et al., 2016; Çelik, 2016; Grass and Fischer, 2016; Gutjahr and Nolz, 2016)

2.3.1. Problem definition and research design

Two approaches are applied in most HO research. In the first approach, scholars rely on their modeling skills, focus on a research problem (which is usually isolated from its context), and then develop, test, and suggest a model for decision making in a humanitarian setting. They use hypothetical data and in some cases historical data from previous reports, databases, or software (e.g., Hazus, 2016; EM-DAT, 2017) to develop scenarios or to simulate and present the model's results (La Torre et al., 2012). Many scholars criticize this research process. For example, Galindo and Batta (2013) as well as Kunz et al. (2017) discuss the lack of collaboration with practitioners (i.e., humanitarian logisticians, warehouse and inventory officers) and humanitarian organizations as a key limitation of many studies. This means that researchers are unable to identify the actual research needs, challenges, or resources, or to incorporate these into their models' objectives, assumptions, and constraints. Anaya-Arenas et al. (2014) assert that a gap remains between the objectives of the optimization and the actual managerial problem. In addition, relying on hypothetical data does not lead to reliable models being employed in practice. While accepting the difficulty of collecting or accessing proper data in this setting, Pedraza-Martinez and Van Wassenhove (2016) suggest that researchers should spend time gathering data from different resources and then clean and interpret them properly before using them in decision-making models or in theory development endeavors. Working closely with humanitarian organizations can facilitate access to their internal data, even though researchers may be required to handle considerable missing data or to support organizations in collecting the data by suggesting routines or systems for data recording.

The second approach begins from a real practical challenge or problem (Figure 2). Here, researchers show their interest and intent in solving real problems, and thus they collaborate with humanitarian organizations to structure the problem and to discuss the best ways to approach it. The problem itself may be defined by a humanitarian organization or co-defined

between practitioners and researchers, as suggested by Kunz et al. (2017). In any case, researchers play an important role in structuring the resultant research problem. In addition to solving the research problem, these studies aim to influence the HO in question and to conduct improvements in a specific humanitarian operation. Accordingly, the research design includes application in a real case and/or at least the dissemination of findings to practitioners. Unlike in the previous approach, the modeling goals and assumptions are closer to practitioners' problems and context. Therefore, the collaboration with other stakeholders, such as donors, governments, and private companies, becomes constructive especially when academics act as facilitators in structuring the research problem (Pedraza-Martinez and Van Wassenhove, 2016). However, this approach requires academics to show an adequate understanding of the humanitarian context and operation before starting the project. According to Gupta et al. (2016), the model's recommendations have to be built on the current processes, and if there is a need for change, sufficient effort must be given to convince practitioners to change them.

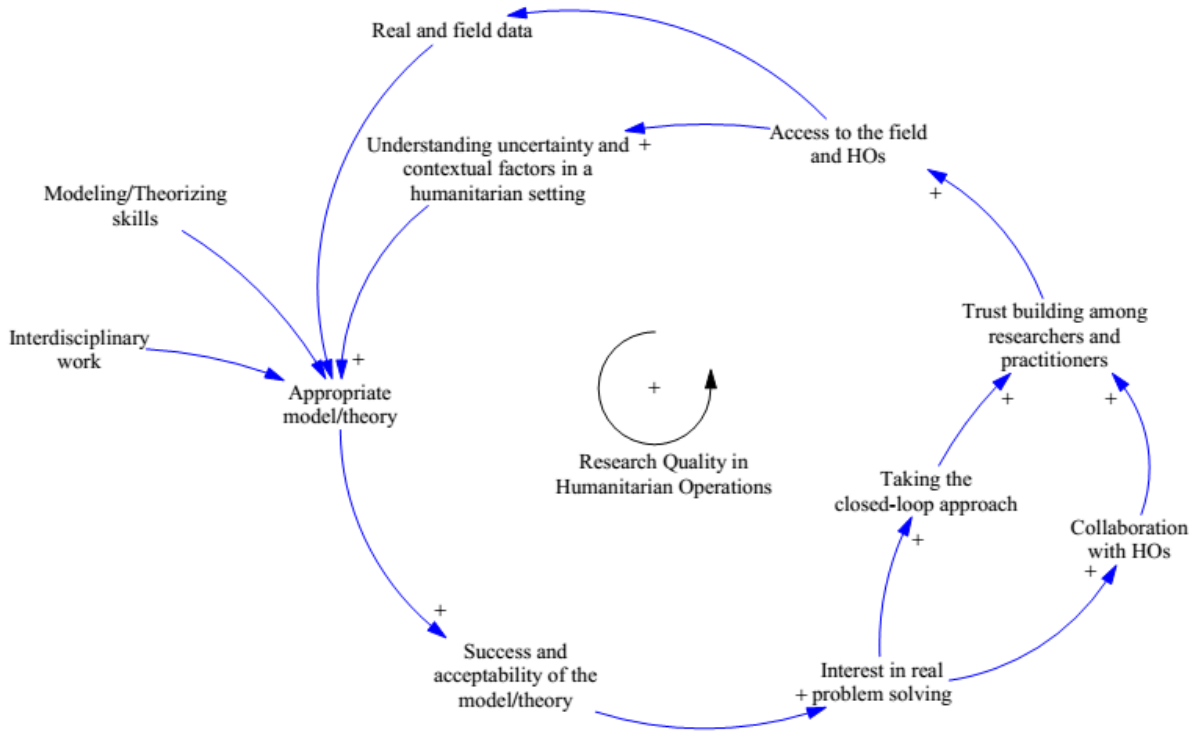

Figure 2. A closed-loop approach to HO research

Strategies such as collaborating with humanitarian organizations and using the closed-loop approach (i.e., supporting humanitarian organizations in incorporating the models and recommendations in their systems and processes) in research can lead to higher trust among researchers and practitioners (Pedraza-Martinez and Van Wassenhove, 2016; Kunz et al., 2017). In such an approach, practitioners understand the potential usefulness of the study and provide researchers access to their internal resources and meetings, give interviews, or allow researchers to run data collection sessions. Researchers can use real data and field data in their study, and they can obtain a good understanding of the uncertainties and contextual factors in a humanitarian setting. These two inputs are as essential as research skills in theoretical reasoning and modeling in order to ensure that the research is both rigorous and relevant.

Furthermore, interdisciplinary work with researchers in information systems, behavioral studies, and social sciences enhances model quality. All these activities increase the likelihood of model success, feasibility, and acceptability by practitioners. Furthermore, the implementation phase of the research opens more avenues for joint activities among researchers and practitioners. Kunz et al. (2017) suggest 10 rules for conducting relevant humanitarian research: knowing the context, selecting problems that matter, defining the performance metrics, having open agendas, setting long-term partnerships, getting involved in data collection, validating findings with the organization, translating, disseminating results, and coordinating the research activities.

2.3.2. Understanding the contextual factors in the humanitarian environment

Obtaining a good understanding of the humanitarian context is vital for HO researchers. The differences among the types of disasters, the affected regions, or the diverse characteristics of

humanitarian organizations and their access to resources should be included in extending or developing theories and decision-making models in HO.

First, disasters, their impact, and their incident evolution have vast differences. Disasters can be natural and man-made, such as terrorist threats, conflicts, and wars (Altay and Green, 2006). Disasters can be fast or slow at the onset, and they can trigger one another in a cascade. Furthermore, the same region can experience different types of disasters. La Torre et al. (2012) present an example of the damage caused by the rainy season in Haiti after the 2010 earthquake; this damage entails two types of disasters with their own characteristics and challenges. The appropriateness of the type of approach and model depends on these characteristics. For example, a time window is available for decision making prior to the actual disaster in slow-onset disasters such as droughts and even when observing the path of an upcoming hurricane or typhoon. Conversely, other disasters leave less or no time at all for acting prior to their impact even if preparedness and mitigation efforts can be applied to them as well. The urgency, size, and incident evolution of a disaster are also reflected in the availability of timely data for decision making and the potential access of researchers to such data. The urgency of a decision may override the possibility of even collecting the data to run a specific model that can help in optimizing it. Surprisingly, Gupta et al. (2016) reveal a high number of HO papers claiming that their findings can be apply to any natural and man-made disasters. This fact is questionable, and the authors have to validate their assumptions and solutions based on the disaster type and attributes.

Second, the characteristics of humanitarian organizations and their differences with commercial firms have to be incorporated in the studies. Humanitarian organizations are different in terms of size, working routines, resources, experiences, and access to new technologies. For example, transportation models for humanitarian organizations with a single depot are different from those with greater resources with multiple depots or access to

communication technologies in the affected region (La Torre et al., 2012). Humanitarian organizations are different in their safety perceptions in different regions, and this difference affects their level of risk-averse behavior, which influences decision making, such as in distributing routes or in hiring international or local drivers (La Torre et al., 2012). The political hierarchy of humanitarian organizations is applicable for multi-attribute, or multi-objective planning and decision making methods (Altay and Green, 2006; Caunhye et al., 2012; Leiras et al., 2014).

Third, humanitarian organizations do not operate in a vacuum; that is, they interact or collaborate with many stakeholders, such as donors, local governments, communities, and the media. These stakeholders have diverse perspectives and sometimes competing objectives in delivering aid to beneficiaries (Gutjahr and Nolz, 2016). However, Leiras et al. (2014) reveal that most of the reviewed studies adopt a single perspective and suggest future studies to observe and model the interaction among the stakeholders in their analysis.

Fourth, considering the local environment and the cultural and political issues in the affected region is important. Corruption, weak government, poverty, and (historical) conflicts in the region affect the emergency relief distribution or recovery operations (e.g., relief timeline, type of products or services, and their providers) (White et al., 2011; La Torre et al., 2012; Pedraza-Martinez and Van Wassenhove, 2016). Researchers should consider analyzing the effects of these factors in their modelling, because the usefulness of the model and its recommendation may be significantly reduced when these factors are disregarded.

2.3.3. Acknowledging the uncertainties in HO

Apart from the contextual factors in disaster types, the variety of humanitarian organizations and of stakeholders operating in any disaster setting, and the specificities of the local environment, disasters also come with a number of important uncertainties that restrict HO.

First, humanitarian organizations have to deal with demand uncertainty given that the location, time, and impact of a disaster remain unclear. Bayram (2016) contends that the lack of demand information significantly affects evacuation planning before a disaster occurs. Moreover, supply quantities and resources from international and local humanitarian organizations and beneficiaries are uncertain (Anaya-Arenas et al., 2014). Bayram (2016) believes that the main reason for the failure of the evacuation operation during Hurricane Katrina in 2005 **was** the assumption that all residents have access to personal vehicles, which was not the case for everyone. However, it is generally not possible for HO research to assume that demand is known in the first place.

Burkart et al. (2016) review the interface between funding and humanitarian supply chain (e.g., nature of funding, funding sources, restrictions on funding, acquisition, and allocation of funding). This study reveals several reasons for the increased uncertainty in the amount of supplied funding and the ways of its spending. For example, donor preferences for quick and short responses may not be consistent with the operational performance objectives, such as effectiveness and efficiency, nor with delivering sustainable solutions. Donor regulations force humanitarian organizations to use donations for specific endeavors (e.g., projects, regions, target beneficiaries, and timing), which decrease the flexibility of HO in using suboptimal performance indicators or earmarking. Therefore, models that assume unlimited budgets or known or fixed budgets are questionable. Moreover, instead of assuming unlimited budgets, models need to consider how resultant budget cuts can be divided across various dimensions of an operation following equity considerations.

Second, many HO models rely on either a given infrastructure or knowledge about infrastructural damages. Caunhye et al. (2012) note that optimization models rely on data availability and that researchers should examine the limited or potential damage to communication and transportation systems and its consequences for data accessibility.

Caunhye et al. (2012) refer to the Haiti earthquake and Indian Ocean tsunami as two examples in which communication breakdown and infrastructure damage inhibit the HO. For La Torre et al. (2012), transportation models should acknowledge the limited technology of (local) vehicles and the unexpected events that may occur on the routes. According to Bayram (2016), studies including the infrastructure uncertainty in the evacuation literature are limited, and researchers need to consider the vulnerability of the transportation and shelter network structure in their modeling.

Third, beneficiaries' behavior and actions (Caunhye et al., 2012; Bayram, 2016; Gupta et al., 2016, Gutjahr and Nolz, 2016) should be captured in realistic models (Gutjahr and Nolz, 2016). Bayram (2016) highlights the role of people's reactions to disasters in demand forecasting and modeling traffic management. For example, in evacuation models, people do not follow optimal solutions (Caunhye et al., 2012) or may not follow the routes suggested to them because of their interest in joining their family or collect their belongings. These behaviors may be different among families with children, aging people, those with stronger social networks, and people with different levels of risk perceptions and confidence in the evacuation authority and in the authorized evacuation process (Bayram, 2016; Gupta et al., 2016). Bayram (2016) also refers to the driver behavior in a disaster, in which time pressure differs from that in a normal situation.

2.3.4. Choosing appropriate methods

Data. Gupta et al. (2016) categorize the types of data in developing a valid model into three groups: (1) field and archival data collected by questionnaires, personal interviews, observations, or secondary data records, (2) real data collected by exploring a real-life disaster, and (3) hypothetical data based on authors' presumptions. The study reveals that most extant HO studies use hypothetical data (45%) or real data (39%), 11% use field data, and 5% do not

use any data. Relying on hypothetical data questions the validity and accuracy of models (Gupta et al., 2016). Scholars suggest using field and real data from previous HO to develop scenarios and to evaluate and compare models (La Torre et al., 2012). Building and testing models through these data resources increases the practitioners' trust in the model outcomes and facilitates their acceptability by humanitarian organizations (Gupta et al., 2016).

Research Methods. Studies reveal that simulation and modeling are mostly used in HO research (Altay and Green, 2006; Natarajarathinam et al., 2009; Kunz et al., 2012), and that mathematical programming is the most applied among modeling techniques (Galindo and Batta, 2013). Kunz et al. (2012) observe that 27% of the reviewed papers use case studies and surveys. Besiou and Van Wassenhove (2015) argue that researchers need to understand the reality of HO and the real problems of humanitarian organizations. For this purpose, case studies, surveys, content analysis of reports and news, and field studies are not only relevant but also enable research to properly represent HO problems.

In modeling complexity in a humanitarian setting, Burkart et al. (2016) observe that scholars have recently used modeling methods, such as game theory, agent-based modeling, and system dynamics, to describe complex HO problems. Soft OR methods enable researchers to structure complex problems that entail multiple stakeholders with diverse and competing interests (White et al., 2011; Galindo and Batta, 2013; Hoyos et al., 2015).

Gutjahr and Nolz (2016) review multicriteria optimization (i.e., Pareto, lexicographic, scalization, goal programming, compromise programming, and analytic hierarchy process) in humanitarian organizations. According to the study, testing the usefulness of the models and methods in practice in real situations is important and insightful but is usually missing in previous studies.

All methods have pros and cons, but HO research rarely discusses the limitations of the methods and their complementarity. Galindo and Batta (2013) contend that there is a need for some advice when deciding on the proper methods for specific situations. In addition, Pedraza-Martinez and Van Wassenhove (2016) suggest that researchers should use diverse methods of data collection and analysis and triangulate the results.

2.3.5. Incorporating uncertainty into the modeling

Correct assumptions. Any model is based on a set of simplifying assumptions. These assumptions should be based on the actual, real-world problem context and should not compromise the applicability of the model. After understanding the contextual factors and acknowledging the uncertainties in a humanitarian setting, researchers can develop realistic assumptions to build their decision-making models. Several studies stress the vital role of analyzing the suitability of models' assumptions, which may vary according to disaster type, region, and HO (Galindo and Batta, 2013; Gupta et al., 2016). For example, Grass and Fischer (2016) and Anaya-Arenas et al. (2014) discuss the assumptions on the deterministic or stochastic data demand values, heterogeneous vehicle fleet, intactness of transportation links and facilities, multi-commodity network context, and multi-disaster and a multi-period setting. Galindo and Batta (2013) analyze the most used assumptions in previous studies and categorize them into reasonable, limited, and unrealistic assumptions.

Anaya-Arenas et al. (2014) review studies on relief distribution networks and observe that the objectives and constraints of models are rarely consistent with the characteristics of relief distribution activities. The studies use a single-period planning horizon and focus on a single commodity. Half of the models also focus on a cost objective, which in itself may be limited and unsuitable. Some performance objectives may be more relevant and appropriate than others. Again, working together with practitioners can help to determine these objectives. The

study calls for models based on realistic assumptions that can be relied upon and applied by practitioners.

To capture uncertainties, decision-making models can work with historical data, rely on data from needs assessment activities of humanitarian organizations, and/or work with stochasticity. Hoyos et al.'s (2015) review focuses on the latter. In another paper, Grass and Fischer (2016) review studies that apply two-stage stochastic programming for modeling uncertainties and time-dependent decisions in disaster management. However, Leiras et al. (2014) observe that the number of studies using stochastic applications in mathematical programming is less than the studies using deterministic models, at 34 against 49. Given the uncertainties in a humanitarian setting, the authors assert that the stochastic models are more appropriate to deal with complexity and uncertainty of the amount of supply and demand.

La Torre et al. (2012) reveal that studies on disaster relief routing use two-stage stochastic programming models but in a single-period setting. In addition, most evacuation planning studies are deterministic and assume a single hazard scenario (Bayram, 2016). To include uncertainty in HO models, scholars suggest using multi-period/multistage stochastic models (Hoyos et al., 2015; Gutjahr and Nolz, 2016). As a network of actors conducts HO, using a one- or two-echelon network does not appropriately present the reality. Therefore, using several multi-echelon supply chains is more appropriate in this setting (Grass and Fischer, 2016). Bayram (2016) suggests using game theoretic approaches especially for HO in conflict zones or for evacuation planning during terrorist threats. In these settings, there are two groups of actors: attackers (e.g., terrorists) who aim to increase the losses, and defenders (e.g., HOs, police) who aim to minimize the effect of attacks and evacuating people to safe areas.

Objective functions. HO research has the goal of assisting practitioners in decision-making processes or increasing the SCM capabilities of a specific humanitarian organization. Identifying proper (i.e., practical and relevant) objective functions is vital for the success of

their application by practitioners (Anaya-Arenas et al., 2014). Scholars argue that relying on traditional objectives from the commercial sector is not adequate, and that the objectives have to represent the humanitarian context with its own characteristics by customizing objectives and assumptions. For example, Holguín-Veras et al. (2013) suggest using deprivation costs as a measure for human suffering in the response phases of HO.

Çelik (2016) presents a summary of the objectives used in the studies on network restoration and recovery in a humanitarian setting, and reveals that efficiency-based measures are essential in the papers reviewed. In another study, Hoyos et al. (2015) observe that in OR models with stochastic components, the objectives are cost minimization, unsatisfied demand, and coverage maximization. Building on Gralla et al. (2014), Gutjahr and Nolz (2016) suggest seven criteria/objectives in optimization models in a humanitarian setting: cost efficiency, response time, travel distance, coverage, reliability, and security, and equity. Their review shows that cost objective, response time, coverage, and travel distance are the ones mostly included in the studies and calls for the inclusion of other relevant objectives, including reliability, security, and equity, in a humanitarian context. In addition, the study suggests that in including security as an objective, models have to involve not only probabilistic concepts but also game-theoretic concepts, especially in man-made disasters (Gutjahr and Nolz, 2016).

The decision on the number and the types of objectives is not straightforward. Some cases have trade-offs between objectives (Holguín-Veras et al., 2013; Gralla et al., 2014), and thus the decision to use one objective is problematic. For example, focusing on responsiveness may lead to inefficacies through oversupply and increased complexities in coordination, traffic volumes, and scheduling (Caunhye et al., 2012). Balcik et al. (2016) observe that only a few studies use multi-objective modeling and optimization techniques.

A recommendation for researchers is to work with humanitarian organizations to develop and choose the right objective function in their research. Considering all objectives at the same time or for any single phase of disaster management is not relevant. For example, maximizing the speed of delivery and quantity of goods is appropriate in the rapid response phase of HO. In the early response phase, beneficiaries have urgent needs, practitioners have to make quick decisions, and collecting complete need assessment information is not possible. Conversely, adequate time can be had for planning in the recovery phase, and therefore equality in delivery can be targeted as one of the models' objectives (La Torre et al., 2012). In designing supply networks for the prepositioning of disaster relief items, using cost objectives is acceptable given the medium to long-term nature of the program (Pedraza-Martinez and Van Wassenhove, 2016).

Integrated Models. Scholars contend that researchers should consider the relations and interdependency among problems or decisions within and between the disaster management phases. Integrated models take several problems, solutions, or elements of disaster management into account simultaneously. For example, post-disaster network restoration (i.e., post-disaster vulnerability and repair of the network) can potentially affect facility location, inventory prepositioning plans, and relief transportation decisions (Faturechi and MillerHooks, 2014; Çelik, 2016). Moreover, search and rescue activities (i.e., debris transportation, road repair, relief delivery, and evacuation) are related to one another, and the interdependency among decisions should be considered in an integrated approach (Özdamar and Ertem, 2015). The location of distribution centers, inventory positioning and distribution logistics can be modeled in an integrated model (Gupta et al., 2016).

However, Anaya-Arenas et al. (2014) observe that integrated approaches are not common and that studies mostly focus one phase of disaster management. For example, 8 of our 87 reviewed articles on relief distribution networks consider the location and transportation problems

simultaneously, which are two activities in relief distribution management. In another study, Bayram (2016) reveals that although the evacuation of the population in the aftermath of a disaster is related to managing the emergency response, studies rarely consider the two simultaneously.

The humanitarian supply network includes many organizations that cooperate with one another, for example, through initiatives such as the cluster approach, in which groups of humanitarian actors work together in different sectors of humanitarian action (e.g., shelter, food security, and education) (UNOCHA, 2017). Therefore, it is appropriate to extend the boundary of problem definition and to conduct research on HO at the network level and beyond the limitations and resources of single organizations with implications for any HO model (Galindo and Batta, 2013). In addition, a humanitarian organization can take a larger perspective and consider its problem not in a specific disaster and region but in all its activities across the world. Pedraza-Martinez and Van Wassenhove (2016) acknowledge this limitation of studies and call for taking a multi-disciplinary approach by interacting with multiple stakeholders when we aim to approach, solve, or explain multiple-issue problems.

2.3.6. Use of enabling technologies for model development and implementation

Apart from developing HO models, determining their feasibility in application and implementation is important. Practitioners have limited time and usually work under time pressure and in a chaotic environment with diverse demands. Moreover, not every practitioner has expertise in understanding models and their implementation. Accordingly, decision support systems and their user friendliness are vital in the success of applying models by practitioners. Özdamar and Ertem (2015) discuss the applications of information systems in humanitarian logistics. Using methods developed for commercial applications does not fit the needs, context, or scale of HO. The computational requirements of most models do not allow for their

application in actual disasters, and too simple and overly complex models may lead to them not being solvable.

Galindo and Batta (2013) call for more research on the application and applicability of decision support systems for HO to facilitate decision making in a humanitarian setting. Özdamar and Ertem (2015) contend that only a few scholars have attempted to integrate their models with a decision support system using real-time data technologies (e.g., GIS or maps). Gutjahr and Nolz (2016) find that integrating models with information systems is an interdisciplinary task and requires researchers from different fields, such as information system, algorithms developers, and humanitarian practitioners.

The next issue is related to the solution algorithms available for models that fit the humanitarian context. Models developed to be multi-objective, multi-period, or multi-problem are complex and require considerable time and data to provide reliable solutions and to be more useful in the field. A main limitation of optimization models is that they rely on timely data availability, which may not be possible in the aftermath of a disaster because of difficulty in accessing the field or a communication breakdown (Caunhye et al., 2012).

Balcik et al. (2016) observe that general-purpose solvers (e.g., CPLEX, LINGO, and Gurobi) are commonly used in stochastic programming models but are not adequately suitable in large-scale problems in a humanitarian setting. They are limited in the number of scenarios and require considerable computing time. Scholars suggest a need for algorithms that are capable of optimizing large models in a short or reasonable time (Anaya-Arenas et al., 2014; Grass and Fischer, 2016).

Access to data can change during the period of responding to a disaster (La Torre et al., 2012). Nowadays, access to real-time data is more feasible than before, allowing for updates and the use of dynamic parameters in the models. For example, the use of remote updates provides the

possibility of practitioners accessing data without regularly sending staff to the affected area. In addition, information update systems can be integrated with solution algorithms (Çelik, 2016). Özdamar and Ertem (2015) suggest the use of online algorithms in HO decision-making models, and Bayram (2016) recommends systems applied in urban transportation planning studies to be used in disaster evacuation planning (e.g., intelligent transportation systems and advanced traveler information systems).

3. Discussion

The previous section reviews a set of common methodological concerns in past studies that should be addressed when using modeling or empirical methods in the context of HO. In this section, we suggest a meta-process for research on HO and elaborate on the values of using mixed methods and combining empirical methods with analytical methods in humanitarian OR.

3.1. A meta-process for research on HO

Sodhi and Tang (2014) propose a four-stage process for knowledge development involving awareness, framing, modeling, and validation. They argue that one research method is the most suitable for each stage of knowledge development: "(1) case study approach for awareness, (2) empirical methods for framing, (3) analytical modeling for modeling and analysis, and (4) behavioral methods for validation in the real world." We build on this framework and suggest a meta-process for research on HO (Figure 3).

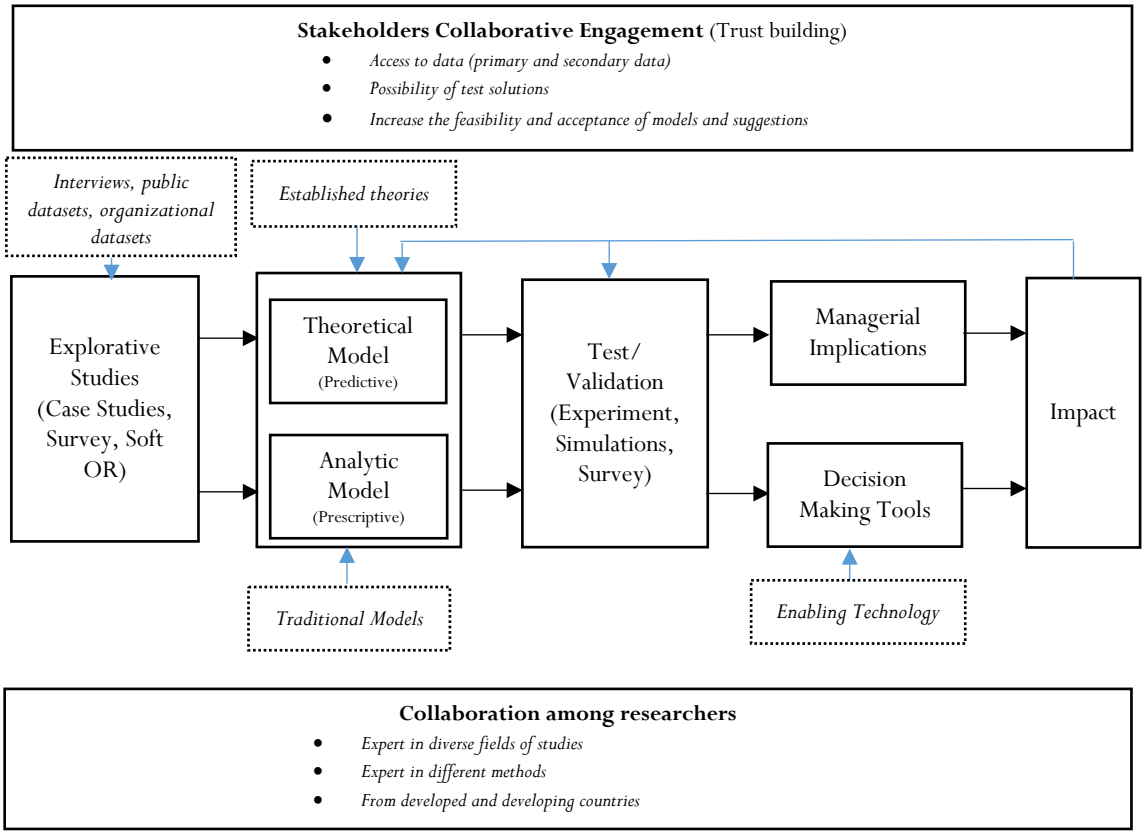

Figure 3. A meta-process for research on HO

The first stage of a research stream is about creating awareness. In this stage, research on a selected topic starts with explorative studies to motivate research and develop taxonomies or descriptive frameworks. Methods such as case studies or descriptive surveys can be particularly useful in this stage. Interviewing with informants, collecting internal documents and organizational datasets, and attending meetings enable researchers to provide a detailed and rich explanation of the problem. Problem structuring methods using soft OR techniques, such as system dynamics or strategic options development and analysis, can be insightful (Sterman, 2000; Mingers and Rosenhead, 2004; Ackermann et al., 2014). By engaging different groups of stakeholders (e.g., humanitarian organizations, donors, governments, and private companies), researchers can provide a more complete and neutral picture of the research

phenomenon. This knowledge enables researchers to understand the contextual factors and the different types of uncertainty in a specific context (e.g., decision-making dilemma for a humanitarian organization regarding a disaster in an affected region).

In the framing stage, researchers incorporate this empirical grounded understanding into an analytic model through a set of assumptions or a conceptual framework through constructs and hypotheses. Through a combination of contextual information and research skills, new knowledge can be framed either through (1) the identification of constructs and hypothesizing relationships among them or (2) the identification of variables and assumptions (axioms) and the development of a formal setup. As a next step, quantitative empirical methods, such as surveys or event studies, can be applied to validate certain constructs and to test hypotheses. In another approach, analytical modeling (e.g., mathematical optimization methods, economic analytical models, and simulation methods) allows researchers to create relationships among different factors and actions.

After presenting a theoretical or analytical model, experiments, large-scale surveys, and simulations can be used to test or validate the model and to examine its reliability, generalizability, and feasibility. After observing the results of such a test, the model can then be revised.

The final stage is to provide a set of recommendations for solving the HO problem or developing some practical solutions. First, researchers can explicate the managerial implications of the study and promote its theoretical insights for managers through workshops and training sessions. Second, by relying on the suggested model, researchers can develop decision-making tools and assist humanitarian organizations to incorporate them into systems or processes to apply in practice. Information systems and decision support systems facilitate such initiatives. After conducting these research stages, humanitarian organizations examine

the value of the model, and in the long term, their feedback can be used in the next rounds of system improvements by revising the theoretical and analytical models.

This research process starts from a real HO problem and ends with a model and a set of recommendations to solve the investigated problem. Therefore, the research outcome does not end with a model or a theory that is far from the real world of humanitarian activities. Aside from the above-mentioned main activities in a research stream, there are two supportive activities: (i) stakeholders' collaborative engagement and (ii) collaboration among researchers.

Stakeholders' involvement in the research process assists researchers in two aspects. The first is providing access to internal datasets and documents and accepting the interview invitations of researchers, which are necessary for explorative and prescriptive studies. In addition, stakeholders' engagement in evaluating the models and theoretical insights is needed to increase the acceptance of the recommendations by practitioners. Several studies have used humanitarian organizations' internal secondary data sources, including consumption data at the level of stock-keeping unit by the Operational Center Amsterdam of Médecins Sans Frontières (van der Laan et al., 2016), the UN Refugee Agency's ERP system records (Jahre et al., 2016), and inventory data from the Office for the Coordination of Humanitarian Affairs and the United Nations Humanitarian Response Depot (Acimovic and Goentzel, 2016).

The last point in describing the meta-process is related to the vital role of collaboration among researchers. Most researchers have expertise in a few OR/MS or SCM methods. Therefore, a collaboration among researchers with diverse backgrounds in methods and fields of study (e.g., social science, logistics, OR, and decision support systems) can help researchers to link fields of study and to use mixed methods in their research projects to develop more realistic models (Bayram, 2016). Accordingly, the collaboration with researchers in the affected regions benefits research projects by providing rich information about beneficiaries' requirements,

infrastructure status, and HO in the field (Altay and Green, 2006; Galindo and Batta, 2013). These two strategies enable HO researchers to avoid "islands of methodology" and "disconnection from practice" (Sodhi and Tang, 2014).

3.2. Mixed methods

Other strategies that stem from research can be used to avoid disconnection from practice. One strategy is the use of mixed methods (Spens and Kovács, 2012) or multi-method approaches (Sanders and Wagner, 2011). Often, this approach implies the joint use of qualitative and quantitative methods (Akhtar, 2017), as also indicated by the 19 definitions of "mixed methods" in Johnson et al. (2007). There are four main ways to pursue a mixed methods strategy: (a) the use of an empirical study to underpin model development, (b) the use of an empirical study to apply a model to test the model, (c) the use of two or more empirical methods in the same study, and (d) the combination of the results of several different empirical studies in a joint analysis. The promise of all these strategies is the increase in the robustness of the analysis and results. In fact, most OR/OM journal editors and reviewers have started to require such approaches. However, notwithstanding such requirements by editors, the actual use of mixed methods in HO is rare. A crucial problem is putting the method before the problem. After all, if all one has is a hammer, everything looks like a nail. Instead, strategy (a) should suggest rigorously outlining the problem through empirical research prior to even determining which model or method would be most suitable to address it. Moreover, strategies (c) and (d) can **also** follow such a path. Some good examples in this regard are Mohanty and Chakravarty's (2013) study on the public health supply chain, Haavisto and Goentzel's (2015) study on the key performance indicators of HO, and Bealt et al.'s (2016) study on logistics service providers working together with humanitarian organizations. But, apart from research that lacks any empirical grounding there are other reasons why studies that use mixed methods may be rare.

After all, if several methods are applied in the same research project, the studies may also be of interest to a series of publications rather than just one.

Akhtar's (2017) analysis of mixed methods approaches goes further than the typical strategies, as he outlines the benefits as well as the pitfalls of mixed methods. The mixed methods approach may resolve some problems (i.e., biases, issues with sample sizes, and the possibility of establishing causalities for better predictive analytics), but it cannot solve every problem. For example, network biases can still occur if a group of researchers co-cite one another regardless of the quality of the research in the group. In such a case, false or wrong conclusions may remain because of the strength or size of the network of researchers and not because of the validity of the research. Reaching out to researchers beyond a specific network in specific topics or methods can help to address the problem of the hammer and the potential network bias.

3.3. Combining Empirical Methods with Analytical Methods

Qualitative empirical methods: Using qualitative empirical methods, such as a case study or ethnography, provides facts and real data to understand the research phenomenon and to develop or validate the assumptions and hypotheses in analytical and theoretical models. According to Roger Schmenner, "We would be better off spending more time in the field going after clever, direct variables that can save us from such potentially risky techniques," (Schmenner et al., 2009). These types of explorative field studies are especially needed in fields that are not adequately well developed, and they require a better understanding of the actors, subjects, problems, and the interactions among them (Voss et al., 2002; Yin, 2013). Given the difficulties in collecting real data in the humanitarian context, Sodhi et al. (2012) highlight the development of (preliminary) conceptual frameworks that can guide researchers in the subsequent research stages on the factors or dimensions that require data collection. Applied

methods such as action research (e.g., Reason and Bradbury, 2001; Nair et al., 2011), which aims at case-specific improvements, or design science research, which aims at developing "generic knowledge to support organizational improvement actions" (van Aken et al., 2016), also rely on qualitative empirical methods. The proper application of qualitative empirical methods needs a strong collaboration with humanitarian organizations before and after a disaster strikes, thus enabling them to have access to data and the possibility of interacting with practitioners and managers to formulate problems and develop conceptual models and hypotheses. Sohn (2017) discusses the benefits and challenges of conducting field research in a humanitarian setting.

Problem structuring methods: As the humanitarian context is characterized by a high level of uncertainty, it contains severe problems that are not easily formulated or solved by a high number of humanitarian organizations with diverse viewpoints and often competing objectives. Therefore, problem structuring methods and soft OR can significantly contribute to HO research by shedding light on the problem levels, identifying and analyzing stakeholders, and capturing the complexity and dynamics of influencing factors. Accordingly, researchers and practitioners can structure the problem by clarifying its boundary and relations with other problems and the stakeholders and by developing the model's objectives and assumptions. Previous studies call for the use of more soft OR methods in HO and their combination with analytical models (Galindo and Batta, 2013; Hoyos et al., 2015). Strategic assumption surfacing and testing, soft system methodology, cognitive mapping, strategic options development and analysis, and system dynamics are among the soft OR methods (Mingers and Rosenhead, 2004; Ackermann et al., 2014). Among these, systems dynamics has been applied in HO (Besiou, et al., 2011, Gonçalves, 2011; Gonçalves and Kamdem, 2016).

Survey method: Before 1980, OM scholars mostly used modeling methods (i.e., simulations and optimizations). Afterwards, scholars tended to use empirical methods such as the survey

research. The use of surveys in OM grew in the late 1990s, and a significant number of them were published in top-tier journals (Rungtusanatham et al., 2003). Several scholars have mentioned the lack of survey research in research related to humanitarian settings (Kunz et al., 2012; Burkart et al., 2016). Surveys have been recently used in HO for hypotheses testing (e.g., Nolte and Boenigk, 2013; Moshtari, 2016), for collecting practitioners' viewpoints on the challenges in the humanitarian sector, and for capturing the opinions of stakeholders in disaster-response performance reviews (e.g., Taylor et al., 2015). Furthermore, surveys can be used in (i) exploratory studies to inform analytical modeling and (ii) in studies for testing the models' findings.

Although problems arise in the survey response rates in the humanitarian context as in all other fields, HO researchers can use various extensive guidelines for constructing proper questionnaires, obtaining higher response rates (e.g., Forza, 2002; Rindfleisch et al., 2008; Melnyk, 2012), and following recent advancements in the methodological aspects of survey research. For example, Guide and Ketokivi (2015) call for avoiding the limitations of cross-sectional studies and putting effort to collect and analyze longitudinal databases to test causality relations in theoretical models. Kriauciunas et al. (2011) elaborate on the specific challenges related to a survey's application in a non-traditional context, such as the humanitarian context.

Secondary data: Using secondary data in a humanitarian setting is a growing trend. Humanitarian organizations focus on delivering aid to beneficiaries and on raising funds to do so. Therefore, they usually suffer from a lack of resources to complete and update their internal data sources, which can be usable for data analysis purposes. Researchers have an opportunity to contribute to the development and improvement of the internal datasets of humanitarian organizations (Pedraza-Martinez and Van Wassenhove, 2016) and to elaborate on the benefits of keeping and analyzing data for HO. For example, a project between the World Food Program

(WFP) and Tilburg University enables the WFP to reduce its operational costs and redesign its food basket delivery (Peters et al., 2016).

Scholars are encouraged to cooperate by pooling their datasets and making them available for other researchers to use (Starr and Van Wassenhove, 2014). The Humanitarian Data Exchange is an example of a platform for sharing and using humanitarian data (https://data.humdata.org/). The increasing access to big data and the advances in data analysis methods provide opportunities to offer new insights into or solutions for HO, such as forecasting methods, locating beneficiaries, and understanding their behavior or needs (Starr and Van Wassenhove, 2014; Swaminathan, 2017). Other available datasets used in HO research include EM-DAT data (Acimovic and Goentzel, 2016; Sodhi, 2016), Reproductive Health Interchange data (Berenguer et al., 2016), municipality data (poverty and education) (Jola-Sanchez et al., 2016), hurricane forecast data provided by the National Hurricane Center (Morrice et al., 2016), and datasets provided by Twitter during Hurricane Sandy (Yoo et al., 2016).

Experiment design: When developing a model, modelers mostly use a set of simple assumptions about the context and human behavior (i.e., practitioners, beneficiaries), which may not be fully valid in the real world (Caunhye et al., 2012). Therefore, mathematical rigor does not guarantee the application of the model (Franco and Hämäläinen, 2016). Previous studies indicate that individuals' biases in decision making, their attitude differences with respect to their cultures, and their specific operational conditions can be captured by behavioral OR/OM while developing and testing models [for a review, see Croson et al. (2013), Franco et al. (2015), Franco and Hämäläinen (2016), Sankaranarayanan et al. (2017)]. Franco and Hämäläinen (2016) suggest three critical aspects of behavioral OR influencing the performance of models: actors' behaviors (e.g., modelers, clients, sponsors, and participants), praxis (e.g., meetings and workshops), and methods (e.g., routines for model building, communicating model results, and decision-making procedures). With respect to HO, behavioral operations is

useful in explaining the models' performance in a specific context of humanitarian aid with a high level of uncertainty, in decision making under time pressure, and in providing insights to improve the models and assist the practitioners to understand the biases in their understanding and decision making.

Laboratory and field experiments are approaches that validate a model or evaluate its effect in practice (Bendoly et al., 2010; Gallien et al., 2015). Interestingly, whereas field studies are used in the first phase of HO, field experiments are rare in a humanitarian setting (e.g., Leung et al., 2016). Caro and Gallien (2010) and Gallien et al. (2015b) explain the benefits and applications of field experiments in OM that can be used in a humanitarian setting.

4. Conclusion and implications for researchers and reviewers

4.1. Conclusion

The body of HO research, including the number of review papers in this field, is growing. This study contributes to this body of knowledge with a focus on methodology and methods to improve the research quality, rigor, and relevance of HO research in practice. Several points are specific to HO, such as contextual factors, the problem of incorporating uncertainties into the OR/OM model construction, collecting and analyzing data, and ensuring that HO models can be applied in practice and implemented. Researchers have to update their knowledge on the dynamic context of humanitarian field. Understanding the field and its uncertainties is critical; therefore, using empirical—whether qualitative or quantitative—methods is important in modeling research. Identifying the real problems and priorities in the humanitarian aid sector and considering the changes in the operational routines of humanitarian organizations and advancements in new technologies (e.g., real-time tracking or computerized need assessment systems, forecasting methods, and supply chain software) are critical in conducting rigorous and useful research; otherwise, the solutions offered to humanitarian organizations will not be

related to their needs, and the models will not be applied by practitioners in the end (La Torre et al., 2012, Pedraza-Martinez and Van Wassenhove, 2016).

Relationships with practitioners are key elements in all phases of research, from defining the problem to implementing the model (Kunz et al., 2017). Still, too few HO models are grounded in practical problems, and they are in danger of overlooking relevant constraints rather than working with them. While some HO researchers find practical problems to be too trivial, understanding the actual problems of practitioners is essential for gaining access to data. In fact, working with the actual constraints of the field would lead to more applicable as well as more interesting and innovative models and theories.

Earlier, the balance between the lack of data and the urgency of decision-making was often cited as a reason for why HO research is detached from its application. To date, however, the struggle is partly with big data and its trustworthiness, as well as the need for cleaning and triangulation of the data. As more and more HO technologies are being used, the challenge of data collection is constantly reduced, while, simultaneously, technology development improves the solvability and solution times of models.

Time constraints are endemic to HO, both in research and in practice. Like practitioners, researchers have to collaborate to share and complement their expertise in modeling, case study, or econometrics methods. Moreover, by pooling its efforts, the community can have access or collect reliable data and develop mutual trust with practitioners. The entire community can have a positive relation with humanitarian organizations to initiate future studies and obtain the opportunity to evaluate the models and tools by practitioners in the field, indirectly benefitting the beneficiaries. Once a study follows these critical factors in conducting modeling or theoretical research in this chaotic environment with a set of diverse uncertainties, its results (i.e., theoretical insights, decision making models, and innovative algorithms) can be

applied to other areas with similar challenges and limitations (La Torre et al., 2012, Van Wassenhove, 2006). Moreover, the impact of HO research will depend on how it is embraced by its own field and its own practitioners. Thus, in order to increase its impact, it is vital for scholars and practitioners to work together.

4.2. Implications for researchers and reviewers

HO research has significantly moved forward in recent years, and future studies in this field require passing high standards, which was not the case in previous years. Therefore, reviewers of journals, books, or funding agencies have a vital role in keeping their standards high to raise the research quality in both aspects of rigor and relevance. As a disaster is specific, studies have to be cautious in claiming that their findings are true in any disaster type in any region or for any humanitarian organization (Gupta et al., 2016). Moreover, the limitations of studies have to be discussed extensively. Studies that use hypothetical data only are questionable. Researchers have to be challenged to prove the accuracy of their theory or model by questioning how realistic their extracted assumptions are and how reliable the findings are in practice (Gupta et al., 2016).

We all cross-learn and use theories and traditional models from the commercial sector. Therefore, the value of HO research is based on how we can customize these models in a new context with its specific characteristics with other sectors. Accordingly, researchers have to be transparent in how they investigate and incorporate contextual factors and uncertainty in their empirical setting. They have to convince reviewers that they understand the current research stream by (i) considering and referring to previous research that used different qualitative or quantitative methods or analytical models and by (ii) choosing a proper method for the research stage they focus on (e.g., a detailed case study for explorative and theoretical study and an experimental study for validating models) (Sodhi and Tang, 2014).

Studies should be motivated by a practical problem either by working with humanitarian organizations or by relying on previous explorative studies, which provide detailed information on the topic. A close collaboration with practitioners enables researchers to understand the priority of their problems and constraints (Galindo and Batta, 2013).

We have to encourage studies to use mixed methods. Research methods have limitations, and when the authors triangulate the methods and data from different resources, the conclusion becomes stronger and acceptable by practitioners. Therefore, the findings, recommendations, and theoretical insights offered by studies need to be validated in practice by using simulations and experimental studies or by testing the theoretical model by a different—qualitative or quantitative—dataset. When suggesting a new decision-making model or tool, researchers have to clarify its benefits in comparison with on-going solutions or routines in humanitarian organizations.

Participating in professional conferences (e.g., health and humanitarian logistics conference, Humanitarian Networks and Partnerships Week) and forums in which humanitarian researchers and practitioners interact (e.g., annual conference of organizations such as the International Council of Voluntary Agencies and the Active Learning Network for Accountability and Performance) has several benefits, such as project development and access to organizational data (Sodhi and Tang, 2014). Academics can invite practitioners in joint research projects and even in writing and reviewing papers. Practitioners can comment on whether the presented ideas in conferences or submitted papers in journals "(1) are applicable or implementable to the practice; (2) provide novel insights or new perspectives to management; and (3) help practitioners recognize their situation (i.e. communicates in recognizable ways)" (de-Margerie and Jiang, 2011; p.142). Journals such as the *Journal of Humanitarian Logistics and Supply Chain Management* sometimes invite practitioners to review the relevance and implications of submitted manuscripts (Altay et al., 2015). Moreover, reviewers of research funding

applications are recommended to ensure that applicants have arranged a proper and close relationship with practitioners to conduct their research projects. The problem or topic of the project should not only rely on a gap in the literature review, but it should also be grounded in practice and structured and defined by a group of scholars and practitioners. In addition, applicants should have a solid plan to use different types of data, research methods, and initiatives on how to disseminate the result of their research project by running training sessions or developing processes to facilitate the incorporation of results into the humanitarian organization. It is encouraging that research funding institutions promote more inter-disciplinary research projects and evaluate projects based on their influence on practice (Knight et al., 2016).

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