Looking back and beyond the complex dynamics of humanitarian operations

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Abstract

Purpose – Due to the unknown location, size and timing of disasters, the rapid response required by humanitarian operations (HO) faces high uncertainty and limited time to raise funds. These harsh realities make HO challenging. This study aims to systematically capture the complex dynamic relationships between operations in humanitarian settings.

Design/methodology/approach – To achieve this goal, the authors undertook a systematic review of the extant academic literature linking HO to system dynamics (SD) simulation.

Findings – The research reviews 88 papers to propose a taxonomy of different topics covered in the literature; a framework represented through a causal loop diagram (CLD) to summarise the taxonomy, offering a view of operational activities and their linkages before and after disasters; and a research agenda for future research avenues.

Practical implications – As the authors provide an adequate representation of reality, the findings can help decision makers understand the problems faced in HO and make more effective decisions.

Originality/value – While other reviews on the application of SD in HO have focused on specific subjects, the current research presents a broad view, summarising the main results of a comprehensive CLD.

Keywords Humanitarian operations, Systematic literature review, System dynamics

Paper type Literature review

1. Introduction

Disasters have increased annually worldwide, causing the loss of human life, environmental damage, infrastructure disruption and economic loss (Altay and Green, 2006; Behl and Dutta, 2019). The major disasters of the 21st century include the 2004 Indonesian tsunami, the 2005 Hurricane Katrina on the southern coast of the USA, the 2010 Haiti earthquake and the COVID-19 pandemic. The 2001 terrorist attacks on the USA, the migration of Syrians, Venezuelans and Afghans to other countries were other examples of disasters of significant magnitude.

Disasters are events that disrupt the functioning of a society, leading to human, material, economic and/or environmental impacts or losses due to hazardous events interacting with conditions of exposure, vulnerability and capacity [United Nations Office for Disaster Risk Reduction (UNDRR), 2017]. The growing impacts caused by disasters have highlighted the need for additional guidance, structure and support to improve responses to disaster-imposed challenges (Kim *et al.*, 2018). Support activities that help minimise disaster impacts and deliver relief supplies to affected people in the shortest possible time are known as humanitarian operations (HO) (Leiras *et al.*, 2014; Mishra *et al.*, 2019). Managing the activities performed before and after a disaster to prevent the loss of human life and diminish their impact is known as humanitarian operations management (HOM) (Altay and Green, 2006).

HO involve conflicting objectives of multiple stakeholders (e.g. government, military, local and international aid networks, suppliers, donors and private sector) (Kovács and Spens, 2007; Fontainha *et al.*, 2017), challenging collaboration

The current issue and full text archive of this journal is available on Emerald Insight at: **https://www.emerald.com/insight/2042-6747.htm**

Journal of Humanitarian Logistics and Supply Chain Management
Emerald Publishing Limited [ISSN 2042-6747]
[DOI 10.1108/JHLSCM-07-2022-0082]

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This work was supported by Coordination for the Improvement of Higher Education Personnel (CAPES) [88881.653896/2021-01; 88887.387760/2019-00; 88887.199861/2018-00; 88887.492890/2020-00 – Finance Code 001], the National Council for Scientific and Technological Development (CNPq) [309621/2022-4; 406666/2022-9; 308084/2019-5] and the Foundation for Support of Research in the State of Rio de Janeiro (FAPERJ) [E-26/201.384/2021].

Received 18 July 2022
Revised 30 January 2023
22 August 2023
8 December 2023
8 February 2024
Accepted 10 February 2024

and coordination (Çelik *et al.*, 2012). HO stakeholders operate with extreme resource constraints (human and material) in environments with unreliable information and time-compressed schedules (Besiou and Van Wassenhove, 2021). Therefore, HO pervades complex problems with high degrees of uncertainty, taking place in dynamic environments (Çelik *et al.*, 2012).

The increasing number of people affected by disasters and their impacts worldwide has led to the development of an expansive aid industry (Fontainha *et al.*, 2022), drawing the attention of different stakeholders. In addition to drawing the attention of practitioners, HOM has become an emerging area of interest for academics (Mishra *et al.*, 2019; Besiou and Van Wassenhove, 2021).

Research in HOM relies on the use of analytical tools, including simulation, optimisation, probability and statistics, to support decision makers better understand the structure of the problems they face and the specific solutions that can lead to more effective and efficient courses of action (Altay and Green, 2006; Mishra *et al.*, 2019). One of the most recognised techniques in HOM is simulation, which provides support for conducting experiments in the real world, facilitating the understanding of physical processes, information flow, cause and effect analysis and policy definition (Galindo and Batta, 2013; Mishra *et al.*, 2019).

HO simulations have significantly evolved over the past 10 years (Mishra *et al.*, 2019). System dynamics (SD) has been steadily used in modelling HO (Gonçalves, 2011; Sopha and Asih, 2018; Besiou and Van Wassenhove, 2021), being the most predominant simulation technique in this context (Mishra *et al.*, 2019). The SD method represents dynamically complex problems through computer simulations and provides tools such as causal mapping and simulation modelling (Sterman, 2000). Several researchers have emphasised the excellent fit of the SD method for HOM (Gonçalves, 2008; Kunz *et al.*, 2014; Guo and Kapucu, 2019; Besiou and Van Wassenhove, 2021). Examples of applications of SD in the HOM field include handling material convergence (Patil *et al.*, 2021), evacuation planning (Ahmad and Simonovic, 2001; Simonovic and Ahmad, 2005; Favereau *et al.*, 2020), early warning systems (EWS) (da Silva *et al.*, 2020), capacity building (Gonçalves, 2011), human resource allocation (Gonçalves, 2011; Sopha and Asih, 2018), the performance of humanitarian organisations (Anjomshoae *et al.*, 2017), relief supply allocation (Peng *et al.*, 2014a, 2014b; Rao and Xie, 2014; Xu *et al.*, 2016), facility restoration (Hwang *et al.*, 2015, 2016), vehicle fleet management (Besiou *et al.*, 2011; Besiou *et al.*, 2014) and inventory prepositioning (Kunz *et al.*, 2014).

Thus, considering the progress of using SD simulation modelling in the HO context, this study aims to analyse SD simulation as a research method for improving HOM by answering two research questions:

RQ1. Which topics in HOM drive SD simulation modelling research?

RQ2. What are the gaps and opportunities for SD applications in HO literature?

Therefore, we adopted a systematic literature review (SLR) methodology to address these questions.

The SLR provides a rigorous and well-defined approach for reviewing the available literature on the HO and HOM fields (Thomé *et al.*, 2016). Critical analysis and synthesis provide a structured foundation for understanding and generating discussions on this subject. We deliver three possible SLR outcomes Torraco (2005) proposed – a taxonomy, a framework and a research agenda. The taxonomy classifies extant literature according to topics from the pre- and post-disaster stages. The conceptual framework, illustrated through a causal loop diagram (CLD), synthesises literature based on critical assessment. CLDs consist of variables connected by arrows that denote causal influences among the variables (Sterman, 2000). The research agenda builds on the clusters highlighted by Behl and Dutta (2019) to propose new research propositions (Torraco, 2005). Therefore, this study relied on a systematic representation of the relationships involved in the complex context of HOM.

After this introductory section, Section 2 presents the research methodology. Section 3 describes the academic literature analysis and findings through a subsection of the publications' overview (looking back at the publications) and a subsection connecting the issues mapped through CLD. Section 4 presents the research agenda (beyond publications). Finally, the conclusions are presented in Section 5.

2. Methodology

We use the SLR methodology to select and analyse the extant literature that adopts SD in HOM field studies, map the topics studied (taxonomy), summarise the research in a CLD and develop a research agenda. A literature review is crucial for mapping and analysing the literature and identifying potential research gaps to further expand the knowledge base (Tranfield *et al.*, 2003). Therefore, this study adopted the eight-step approach proposed by Thomé *et al.* (2016) to conduct the SLR:

1. research problem formulation;
2. literature search;
3. data collection;
4. quality assessment;
5. data analysis and synthesis;
6. interpretation;
7. presentation of results; and
8. update of the review.

The Scopus and Web of Science databases were selected for the literature search because of their significant number of indexed journals, according to Mongeon and Paul-Hus (2016). The research considered three groups of keywords defined broadly enough to avoid artificial limitations on the desired documents but still capable of excluding undesirable results (Petticrew and Roberts, 2006):

1. The first group of keywords addresses the method of "system dynamics".
2. The second group of keywords encompasses HO terminologies such as "operations", "logistics", "management" and "supply chain".
3. The third group includes keywords such as "disaster*", "relief" and "humanitarian*" endorsed from previous

literature review papers (Leiras *et al.*, 2014; Fontainha *et al.*, 2017; Cardoso *et al.*, 2023), sudden onset disasters groups and types listed by the Emergency Events Database (EM-DAT) and IFRC slow onset disasters response groups (migration and displacement and food security) [Emergency Events Database (EM-DAT), 2023; The International Federation of Red Cross and Red Crescent Societies (IFRC), 2024].

We searched for titles, abstracts and keywords in Scopus and topics in the Web of Science database in March 2022 (last revised in January 2023), resulting in 1,102 documents from Scopus and 720 documents from Web of Science without initial exclusions. We developed a conceptual matrix in an Excel spreadsheet using data from 1,822 documents. We then manually removed 498 duplicates due to overlap in the Web of Science and Scopus databases.

We adopted the inclusion and exclusion criteria for abstract and full-paper reading. The inclusion criteria were:

- research on major disasters;
- search in the HO field; and
- adoption of SD modelling.

The first inclusion criterion considered papers that encompassed disasters. Disasters are serious ruptures in the functioning of a society, leading to human, material, economic and/or environmental impacts or losses due to hazardous events that interact with conditions of exposure, vulnerability and capacity (UNDRR, 2017). Therefore, we did not consider routine or everyday emergencies, such as the daily responses of ambulances, police or fire departments to routine emergency calls (Altay and Green, 2006).

The second inclusion criterion included studies on HO. HO has a broad scope, encompassing humanitarian logistics (HL), humanitarian supply chains (HSC) and the management activities involved (Nunes and Pereira, 2022). While HL deals primarily with the operational aspects of moving goods, services and information during disasters, involving activities such as procurement, transportation, warehousing, distribution and inventory management (Leiras *et al.*, 2014), HSC management is a broader field that incorporates strategic planning, coordination and optimisation of the entire supply chain to improve the overall effectiveness of HO, including activities such as demand forecasting, procurement strategy development, supplier relationship management, risk assessment and performance measurement (Akhtar *et al.*, 2012; Shafiq and Soratana, 2019).

The third inclusion criterion considered only papers that adopted SD or SD coupled with other techniques for full reading and analysis. Therefore, papers that mentioned SD and encouraged the use of the method but did not use SD as the central methodology were excluded. The exclusion criteria were as follows:

- research on routine problems;
- ecosystem (fauna and flora) disruptions;
- documents without SD modelling;
- documents not available; and
- proceedings and books.

The first author and two other researchers (with experience in HO and SLR) independently reviewed a representative sample of abstracts to ensure that the inclusion and exclusion criteria were unambiguous and yielded reliable results. The abstract agreement index among the three researchers was 100% (Krippendorff, 2018). The first author proceeded with the screening phase by reading all the abstracts and full texts of the selected articles. The topics raised, selected variables and CLD were developed with the involvement of all authors.

A full reading of the selected abstracts resulted in the selection of 79 articles. After document selection through the database search, we conducted a snowball search. This method is characterised by a reference analysis of the selected articles, with the aim of increasing the coverage of the documents to be analysed. Figure 1 summarises the steps in this section, using the preferred reporting items for systematic reviews and meta-analyses diagram proposed by Moher *et al.* (2009) and Page *et al.* (2021).

For the data collection of the 88 papers, we also developed a conceptual matrix in an Excel spreadsheet (Vom Brocke *et al.*, 2009) with a document in each row and column containing the title, abstract, publication year, keywords and references, as well as a space for categorising the works according to the research application to be developed. Creating a standard data-collection procedure allows for full traceability and replicability of the content related to each search step. The data analysis consisted of a bibliometric study to set basic statistics and was carried out using the bibliometrix R tool for comprehensive science mapping analysis.

The data were synthesised and interpreted in steps (Figure 2). After identifying and collecting papers and considering the previously defined scope, topics (themes) in the literature

Figure 1 Flow of information through systematic review phases

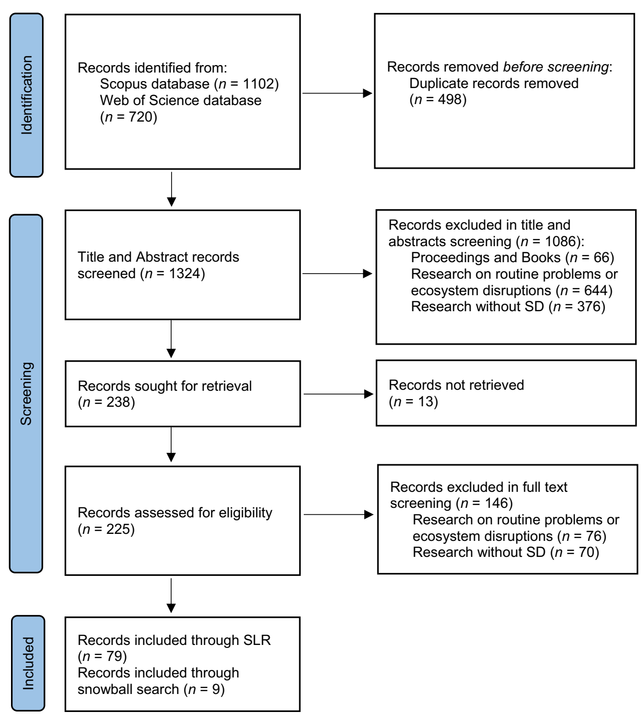

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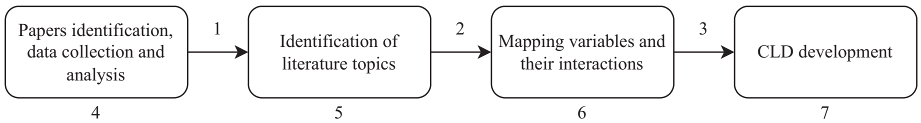
Figure 2 Data synthesis and interpretation steps



Processes:
1 - Inductive iterative process of category building, testing, and reviewing
2 - Inductive iterative process to unify variables with similar meaning
3 - Iterative process of construction based on the variables interactions

Boundaries and scope definitions:
4 - Research scope definition
5 - Analysis aggregation level definition
6 - Variable mapping aggregation level definition
7 - Variable interactions aggregation level definition

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were identified through an inductive process in which categories were derived from the material under examination, using an iterative process of category building, testing and reviewing by constantly comparing categories (Seuring and Gold, 2012). Using an inductive iterative process, the three authors defined the aggregation level of the analysis and arrived at the set of topics presented in Table 2. In addition to these three authors, the aggregation level of the analysis was validated by four experts.

After defining the topics, the variables identified through the SLR (both in the CLDs and texts) were mapped and coded in a matrix with their related descriptions. To align the names and concepts of the variables, translational activity and coding of the qualitative data were performed to ensure the comparability of the findings from the different studies. Three authors defined the level of aggregation of the mapped variables and validated them with the help of four academic specialists.

Finally, using a defined group of variables, the authors iteratively developed the causal diagrams shown in Figures 5–9. Again, the level of aggregation of the interaction of the variables was defined according to the interactions for the development of CLD and was validated by four specialists on the subject.

Sections 3 and 4 present the data analysis, synthesis and interpretation, providing a taxonomy table (Table 2), framework (CLD) (Figures 5–9) and research agenda. The CLD was implemented on Vensim, a standard simulation software that allows users to capture CLDs and develop formal SD models.

3. Results and discussions

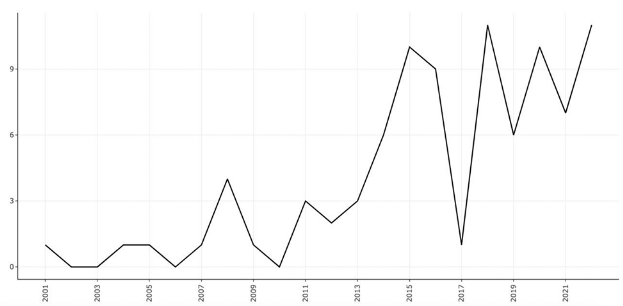
This section encompasses the SLR results.

3.1 Publications overview

As shown in Figure 3, the first paper appeared in 2001, with research publication spikes in 2008, 2015, 2018, 2020 and 2022, reflecting the continuous publication trend of papers adopting SD in HO.

These papers were published in different journals (Figure 4). The most relevant publication channels were the *Journal of Humanitarian Logistics and Supply Chain Management (JHLSCM)*, *Production and Operations Management (POM)*, *International Journal of Disaster Risk Reduction (IJDRR)*, *Annals of Operations Research (ANOR)* and *Natural Hazards*. The theme is multidisciplinary because journals in widely different areas (e.g. *Journal of Construction Engineering and Management, Behavioural Science and Production Economics*) cover the topic.

Figure 3 Annual scientific production



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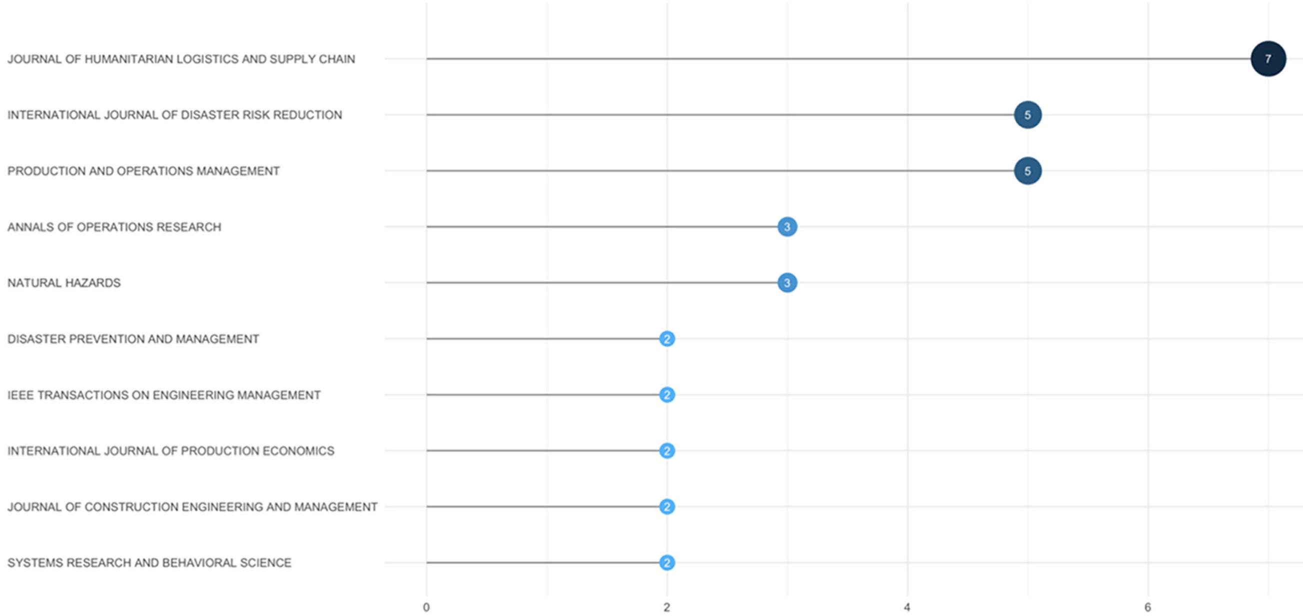
Luk Van Wassenhove and Maria Besiou have published many articles on this theme as first authors or co-authors. The three most cited papers encompassed completely different HO topics. Simonovic and Ahmad's (2005) research highlights an SD model for capturing human behaviour – acceptance of evacuation orders by the area's residents under threat – during flood disaster evacuation. Kunz *et al.* (2014) researched the trade-off between investing in disaster management capabilities such as training staff, pre-negotiating customs agreements with countries prone to disasters and harmonising import procedures with local customs clearance procedures and prepositioning inventory. Besiou *et al.* (2011) illustrated the appropriateness of the SD methodology as a tool for humanitarian decision makers to understand the effect of their decisions on HO.

Table 1 summarises the use of SD based on the analysis of Besiou and Van Wassenhove (2021). Most studies (63%) presented conceptual models or frameworks to explain the research problem or to summarise the findings. A total of 67% were present with CLD, whereas 78% presented stock and flow

Figure 4 Most relevant sources



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diagrams (SFD) or simulation results. Of the papers that adopted an SFD, three did not present data or perform simulations (indicating them as opportunities for future studies); 65% used real data, considering focus group discussions, case studies and semi-structured interviews, whereas 30% considered hypothetical data.

3.2 Mapped relations

Table 2 presents the main topics identified through the SLR, references regarding each topic and mapped variables.

To develop the CLD, we considered a disaster life cycle composed of pre-event (mitigation and preparedness) and post-event stages (response and recovery) (Altay and Green, 2006; Hernantes *et al.*, 2013), as summarised in this section.

3.2.1 Pre-disaster stage

Figures 5, 6 and 7 illustrate the relationships between topics and variables associated with the pre-disaster stage.

The threat of a disaster raises a population's concern about its possible consequences, galvanising people's acceptance of a possible evacuation and limiting the population under threat. Figure 5 shows this *evacuation decision* owing to a threat in the balancing loop (B1). The reinforcing loop (R1) – *disaster concern* – shows that as the population becomes aware of and learns more about the potential consequences of a disaster, the more it recognises the danger and the greater its concern (Ahmad and Simonovic, 2001; Simonovic and Ahmad, 2005). Regardless of the threat, however, a fraction of the population may resist evacuation, either due to material or affective attachment to their homes, causing a delay in the acceptance decision and closing the reinforcing loop (*R*2) of *evacuation resistance* (Berariu *et al.*, 2015). People may also resist evacuation because of previous false alarms (e.g. "Cry Wolf Syndrome") (da Silva *et al.*, 2020).

Disaster concern heightens the need for preparedness, where suitable structures are set up before the occurrence of disasters (Jahre *et al.*, 2016), managing the risks that make the population vulnerable to disasters (Figure 6) through the B2 balancing loop (B2) – *preparedness through risk assessment*.

In addition to preparedness through risk management measures, the literature points to preparedness through training and education, which can affect people's behaviour through increased awareness of danger, knowledge about EWS, escape routes and safe places. Increased awareness and knowledge about the possible impacts of disasters heightens the recognition of danger and raises people's concerns, intensifying the perceived need for preparedness and increasing efforts to undertake disaster training and education.

As the population is better prepared through training on how to behave during a disaster and better educated about its dangers, they learn about EWS, whether to evacuate, items to take in case of an evacuation, possible evacuation routes and safe places to go to when a disaster occurs. Improved disaster education increases the acceptance of evacuation decisions, reduces the population under threat, and closes the balancing loop of *preparedness* via *knowledge of routes and places* (B3) and *preparedness* via *knowledge of EWS alerts* (B4) (Figure 7). Improved training and education also increase people's knowledge and awareness of the impact and dangers of disasters, raising their concerns and closing the loop of *preparedness* via *awareness* (R3).

The evacuation of the population under threat, such as preparedness before a disaster, involves HL and SC aspects, including the necessity of inventory, transportation and location strategies through relocation plans; determination of support points and shelters; definition of evacuation routes; and shelter management, including supplies and capacity administration.

Table 1 SD adoption in publications

References	Conceptual model	CLD	SFD or simulation result	Real data	Hypothetical data
Ager *et al.* (2015)		X			
Ahmad and Simonovic (2001)	X		X	X	
Allahi *et al.* (2018)		X	X		
Allahi *et al.* (2020)		X	X	X	
Allahi *et al.* (2021)	X	X	X	X	
Anagnostou *et al.* (2016)		X	X	X	
Anjomshoae *et al.* (2017)	X	X			
Arboleda *et al.* (2007)		X	X	X	
Armenia *et al.* (2018)		X	X		X
Babaei and Shahanaghi (2018)	X				
Berariu *et al.* (2016a)		X	X	X	
Berariu *et al.* (2016b)		X	X	X	
Besiou and Van Wassenhove (2021)	X				
Besiou *et al.* (2011)	X	X	X	X	
Besiou *et al.* (2014)		X	X	X	
Carpes *et al.* (2020)	X		X	X	
Cohen *et al.* (2013)	X		X		X
Cruz-Cantillo (2014)	X	X	X	X	
Cunha *et al.* (2021)		X			
Cunha *et al.* (2022)	X	X	X	X	
da Silva *et al.* (2020)	X	X			
Diaz *et al.* (2015)			X		X
Diaz *et al.* (2019)			X	X	
Diedrichs *et al.* (2016)	X		X		X
Erkayman *et al.* (2022)	X	X	X	X	
Favereau *et al.* (2020)	X	X	X	X	
Feofilovs *et al.* (2020)	X	X			
Giedelmann-L *et al.* (2022)	X		X	X	
Gillespie *et al.* (2004)		X	X		
Gonçalves (2008)		X	X		X
Gonçalves (2011)		X	X		X
Gonçalves *et al.* (2022)	X		X	X	
Gotangco *et al.* (2014)			X		X
Guo and Kapucu (2019)	X	X	X		X
Guzman Cortes *et al.* (2018)	X	X	X		X
Guzmán-Cortés *et al.* (2022)	X	X	X	X	
Han *et al.* (2008)	X	X	X		X
Harke and Leeuw (2015)			X	X	
Harpring *et al.* (2021)	X	X			
Heaslip *et al.* (2012)	X	X			
Hernantes *et al.* (2013)	X	X	X	X	
Hiltz *et al.* (2013)	X	X			
Hwang *et al.* (2015)	X	X	X	X	
Hwang *et al.* (2016)	X	X	X	X	
Khanmohammadi *et al.* (2018)		X	X		X
Kim *et al.* (2018)	X		X	X	X
Kosmas *et al.* (2022)	X	X	X	X	
Kumar *et al.* (2015)			X		X
Kunz *et al.* (2014)	X		X	X	
Kwesi-Buor *et al.* (2019)	X	X	X	X	
Lawrence *et al.* (2022)	X		X		
Li *et al.* (2019)		X	X	X	
Lin *et al.* (2022)	X	X	X	X	
Magalhães *et al.* (2020)	X		X		
Min and Hong (2011)		X	X		X

(*continued*)

Table 1

References	Conceptual model	CLD	SFD or simulation result	Real data	Hypothetical data
Mishra and Sharma (2020)		X	X	X	
Mishra *et al.* (2019)					
Ni *et al.* (2015)	X	X	X		X
Obaze (2019)	X	X			
Patil *et al.* (2021)	X	X	X	X	
Peng *et al.* (2014b)	X	X	X		X
Peng *et al.* (2014a)	X	X	X	X	
Perrone *et al.* (2020)	X	X			
Powell *et al.* (2016)	X	X			
Powell *et al.* (2018)	X	X			
Pujadi (2017)	X				
Qiu *et al.* (2021)	X	X	X		X
Ramezankhani and Najafiyazdi (2008)		X	X	X	
Rao and Xie (2014)	X		X	X	
Rong *et al.* (2022)			X		X
Santella *et al.* (2009)			X		X
Shi *et al.* (2021)			X		X
Simonovic and Ahmad (2005)	X	X	X	X	
Song *et al.* (2018)	X	X	X	X	
Sopha and Asih (2018)		X	X	X	
Stewart and Ivanov (2019)	X		X	X	
Su and Jin (2008)		X	X	X	
Suarez (2015)	X				
Uddin *et al.* (2018)	X				
Van Oorschot *et al.* (2022)			X	X	
Van Wassenhove and Besiou (2013)	X				
Voyer *et al.* (2015)		X	X	X	
Voyer *et al.* (2016)		X	X		X
Wang *et al.* (2012)	X	X	X	X	
Wu *et al.* (2015)			X	X	
Xu *et al.* (2015)	X	X	X	X	
Xu *et al.* (2016)	X	X	X	X	
Zhong (2018)	X	X	X	X	

Source: Table created by Authors

To exemplify the relationships described in the pre-disaster CLD, we consider two distinct scenarios: a sudden-onset disaster (e.g. flood followed by landslides); and a slow-onset disaster (e.g. drought).

Regarding the former, people living in a landslide-risk area must prepare for the possibility of a sudden-onset disaster. The more people are aware of the dangers associated with landslides (e.g. loss of property and loss of life) and the more they prepare to mitigate those risks. For instance, people may reinforce the structures and foundations of their homes. Furthermore, they can be prepared through education and training, that is, learning about local evacuation routes, safe places and EWS alerts.

Regarding the latter, people living in regions prone to drought can also prepare themselves by mitigating the impact of drought (e.g. with wells, cisterns or other ways to store rainwater) or by training and education in plantations and pastures (e.g. accumulating fodder for use during droughts).

3.2.2 Post-disaster stage

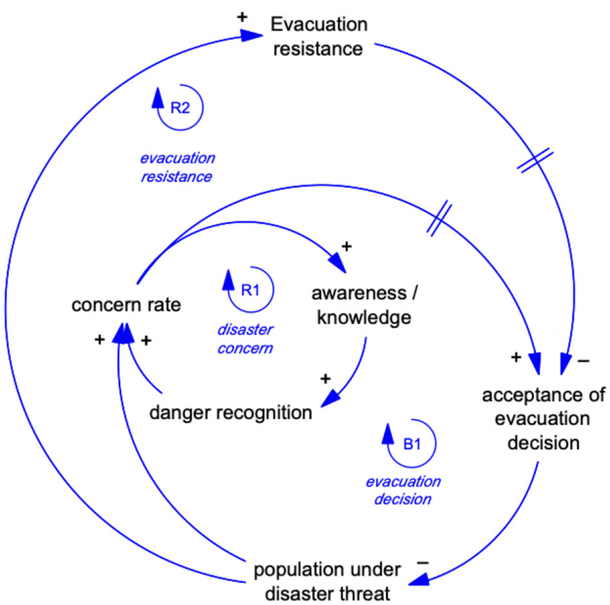
The previous section reviewed the feedback processes described during the pre-disaster stage, whereas this section discusses those during the post-disaster stage. After a disaster strikes, the population of the region is affected. The greater the magnitude of the disaster, the larger the population in need. As evacuation efforts (Berariu *et al.*, 2016a; Uddin *et al.*, 2018; Allahi *et al.*, 2021; Giedelmann-L *et al.*, 2022) are implemented, the need for people is reduced, closing the balancing loop – *population evacuated* (B8) (Figure 8). The population in need pressures humanitarian actors to provide relief and recovery. First, relief efforts are always undertaken by local or regional actors, allocating readily available resources to assist people in need. As relief and recovery operations are put in place, more people are assisted, closing the balancing loop – *population assisted* (B9). The larger the population in need, the greater the pressure to provide relief/recovery and receive media attention. Media attention to the impact of the disaster galvanises international concern, increasing with a delay in the total amount of funds (e.g. local, regional, external and donations) available for relief and recovery efforts. As more funds become available and relief operations mitigate the impact on the affected population, the pressure on humanitarian actors and the need for further

Table 2 Disaster stage, topics, references and variables addressed in the CLD

Disaster stage	Topics	References	CLD variables
Pre-disaster	Evacuation planning and process	Ahmad and Simonovic (2001), Simonovic and Ahmad (2005), Cruz-Cantillo (2014), Pujadi (2017), da Silva *et al.* (2020), Favereau *et al.* (2020), Shi *et al.* (2021), Kosmas *et al.* (2022)	Acceptance of evacuation decision; evacuation resistance; knowledge of EWS alerts
	Population behaviour	Ahmad and Simonovic (2001), Gillespie *et al.* (2004), Simonovic and Ahmad (2005), Powell *et al.* (2016), Pujadi (2017), Favereau *et al.* (2020)	Concern rate; awareness/ knowledge; danger recognition; perceived need to be prepared; acceptance of evacuation decision; evacuation resistance; knowledge of population routes/places
	Preparedness	Gillespie *et al.* (2004), Gotangco *et al.* (2014), Kunz *et al.* (2014), Anagnostou *et al.* (2016), Berariu *et al.* (2016a), Powell *et al.* (2016), Kwesi-Buor *et al.* (2019), Kosmas *et al.* (2022)	Preparedness through training and education; preparedness through risk management measures
Post-disaster	Relief and recovery operation	Ramezankhani and Najafiyazdi (2008), Gonçalves (2008), Gonçalves (2011), Besiou *et al.* (2011), Heaslip *et al.* (2012), Voyer *et al.* (2015), Obaze (2019), Harpring *et al.* (2021), Guzmán-Cortés *et al.* (2022)	Pressure to provide relief/ recovery; relief/recovery operations
	Media coverage	Besiou *et al.* (2011), Heaslip *et al.* (2012), Cruz-Cantillo (2014), Anjomshoae *et al.* (2017), Perrone *et al.* (2020), Kosmas *et al.* (2022)	Media coverage
	Evacuation	Berariu *et al.* (2016a), Uddin *et al.* (2018), Allahi *et al.* (2021), Giedelmann-L *et al.* (2022)	Evacuation
	Funding	Besiou *et al.* (2011), Cruz-Cantillo (2014), Gontangco *et al.* (2014), Ni *et al.* (2015), Voyer *et al.* (2015), Anjomshoae *et al.* (2017), Allahi *et al.* (2018), Guzman Cortes *et al.* (2018), Obaze (2019), Allahi *et al.* (2020), Mishra and Sharma (2020), Patil *et al.* (2021), Cunha *et al.* (2022), Lawrence *et al.* (2022), Giedelmann-L *et al.* (2022)	External funds; local/regional funds; donations; funds allocated to relief/response
	Infrastructure	Ager *et al.* (2015), Arboleda *et al.* (2007), Han *et al.* (2008), Ramezankhani and Najafiyazdi (2008), Su and Jin (2008), Santella *et al.* (2009), Hernantes *et al.* (2013), Hiltz *et al.* (2013), Suarez (2015), Diaz *et al.* (2015), Xu *et al.* (2015), Kumar *et al.* (2015), Hwang *et al.* (2015), Diedrichs *et al.* (2016), Hwang *et al.* (2016), Voyer *et al.* (2016), Armenia *et al.* (2018), Babaei and Shahanaghi (2018), Powell *et al.* (2018), Kim *et al.* (2018), Khanmohammadi *et al.* (2018), Zhong (2018), Diaz *et al.* (2019), Harpring *et al.* (2021), Peng *et al.* (2014a, 2014b), Ni *et al.* (2015), Voyer *et al.* (2015), Song *et al.* (2018), Guo and Kapucu (2019), Guzman Cortes *et al.* (2018), Li *et al.* (2019), Feofilovs *et al.* (2020), Magalhaes *et al.* (2020), Perrone *et al.* (2020), Qiu *et al.* (2021), Lawrence *et al.* (2022), Erkayman *et al.* (2022), Gonçalves *et al.* (2022), Rong *et al.* (2022), Van Oorschot *et al.* (2022)	Disaster magnitude; infrastructure damage
	Logistics capacity	Besiou *et al.* (2011), Min and Hong (2011), Cohen *et al.* (2013), Besiou *et al.* (2014), Kunz *et al.* (2014), Rao and Xie (2014), Peng *et al.* (2014a, 2014b), Ni *et al.* (2015), Berariu *et al.* (2016b), Xu *et al.* (2016), Guo and Kapucu (2019), Carpes *et al.* (2020), Lawrence *et al.* (2022), Guzmán-Cortés *et al.* (2022), Lin *et al.* (2022), Giedelmann-L *et al.* (2022)	Logistics capacity

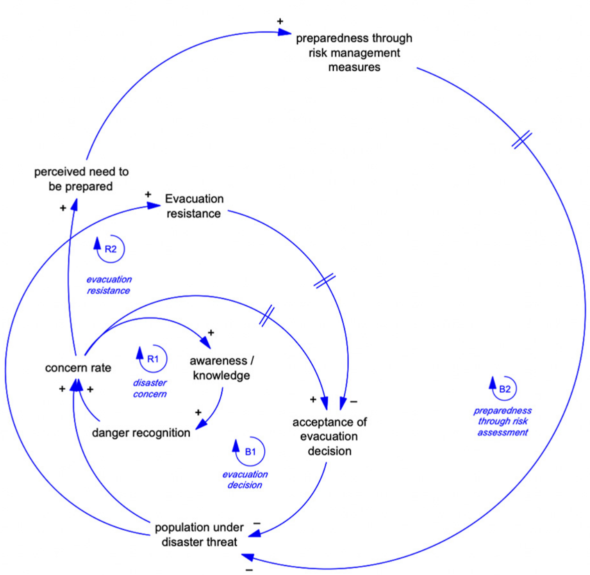
Source: Table created by Authors

Figure 5 Causal structure for disaster threat, concern and evacuation decision (pre-disaster)



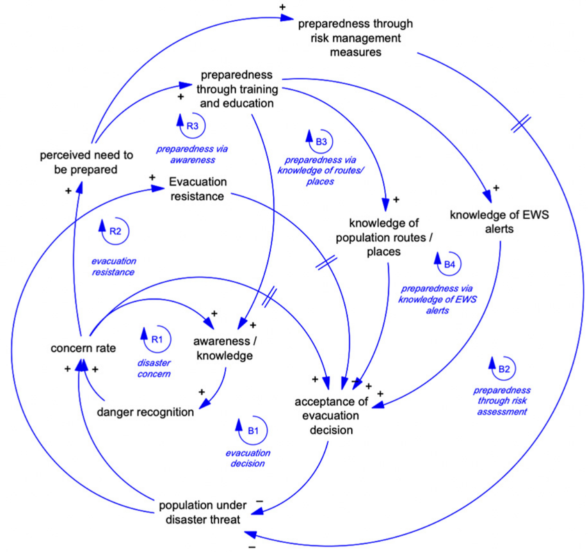
Notes: Variables are captured in black; blue arrows represent connections between variables; two dashes along the arrows capture delays; loop types [balancing (B) or reinforcing (R)] are encircled by arrows; loop names are shown in italics.
Source: Figure created by Authors

Figure 6 Causal structure for preparedness through risk assessment (pre-disaster)



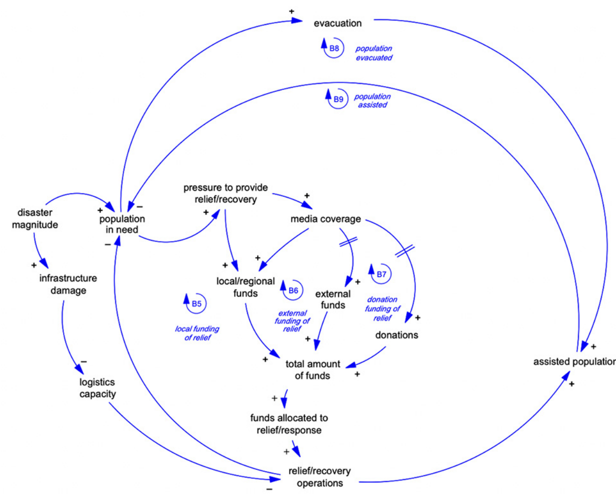
Source: Figure created by Authors

Figure 7 Causal structure for preparedness through training and education (pre-Disaster)



Source: Figure created by Authors

Figure 8 Causal structure for the allocation of funds to relief/recovery (post-disaster)



Source: Figure created by Authors

funding decrease. The feedback processes governing the funds available for relief and recovery operations are captured in the following balancing loops: *local* (B5), *external* (B6) *and donations* (B7) *funding of relief*. As disasters also affect local infrastructure, they curb the logistical capacity of the region, limiting humanitarian relief and recovery efforts to evacuate or assist people and deliver critical supplies and equipment (e.g. water, generators, health kits and sanitation kits).

Relief and recovery operations take root in the HSC as it becomes necessary to forecast demand and assess needs, mobilise resources (drugs, supplies and human resources), and make decisions related to purchasing, inventory, transport and network planning according to the damaged infrastructure, distribution transportation, information systems and reverse logistics, among others.

Consider the scenarios of slow-onset (e.g. drought) and sudden-onset (e.g. flood) disasters again. When faced with droughts or floods, people are evacuated to different regions or temporary shelters. Humanitarian relief and recovery operations can complement assistance to affected people by sending water tanker trucks to drought-affected regions or by leading search and rescue (SAR) efforts in flooded areas.

Several studies have focused on fleet management, resource allocation and distribution (Besiou *et al.*, 2011; Min and Hong, 2011; Besiou *et al.*, 2014; Peng *et al.*, 2014a, 2014b; Kunz *et al.*, 2014; Rao and Xie, 2014; Ni *et al.*, 2015; Xu *et al.*, 2016; Guo and Kapucu, 2019; Berariu *et al.*, 2016b). Other cover services in HO, such as debris management, housing recovery and health-care services, are presented in detail in Table 3.

3.2.3 Pre- and post-disaster stage.
The need to allocate scarce resources between disaster preparedness and relief/recovery creates an intrinsic relationship between the pre- and post-disaster stages. The means of disaster preparedness identified in the literature encompass risk management, education and training of the population, stock prepositioning and humanitarian organisation capacity building (Figure 9).

Disaster preparedness deals with the activities implemented by communities, governments and humanitarian actors before a disaster to minimise its adverse effects (Van Wassenhove, 2006; Kunz *et al.*, 2014). Disaster preparedness allows humanitarian actors to react faster, putting in place resilient processes (e.g. robust supply chain design) to ensure the proper flow of critical supplies (i.e. through prepositioned items or avoiding bottlenecks caused by closed borders) (Stewart and Ivanov, 2019). Prepositioning relief supplies allows humanitarian organisations to reach affected communities quickly and effectively (Kunz *et al.*, 2014; Ni *et al.*, 2015; Harke and Leeuw, 2015). Although prepositioning is an important and effective preparedness policy, it requires high capital investment and holding costs; therefore, its implementation takes time.

However, donors typically finance relief and recovery efforts only after a disaster strikes, often neglecting the importance of preparedness (Kunz *et al.*, 2014; Ni *et al.*, 2015). For this reason, Gotangco *et al.* (2014) state that local governments should spend their funds on initiatives that help decrease local vulnerability before a disaster occurs. Feofilovs *et al.* (2020) corroborated this view by adding an "investment disaster risk reduction" variable to their CLD, explaining that the larger the available local budget, the greater the investment in disaster risk reduction. Consequently, in the event of a disaster, investment in preparedness generates less damage and fewer financial losses.

While there is agreement in the literature that preparedness can increase performance, more investment is needed in preparedness activities in practice (Stumpf *et al.*, 2023). Limited systemic thinking and fact-based evidence research regarding the investment impacts are considered reasons why this potential remains untapped (Kunz *et al.*, 2014; Jahre *et al.*, 2016; Anjomshoae *et al.*, 2022; Stumpf *et al.*, 2023).

The relationship between the pre- and post-disaster stages also appears through humanitarian organisations' capacity building (e.g. hiring and training people, capturing lessons learned and structuring organisational processes), as defined by the reinforcing loop – *lessons learned impact on capacity* (R4). As relief and recovery operations successfully assist affected people, humanitarian organisations learn what works and what does not. Such lessons lead to more effective processes and institutionalisation in humanitarian organisations, increasing their capabilities and operational effectiveness. Gonçalves (2008), Gonçalves (2011), Besiou *et al.* (2011), Sopha and Asih (2018) and Harpring *et al.* (2021) addressed capacity-building topics.

In addition, the greater the number of people needing help, the greater the pressure to support humanitarian organisations in relief and recovery operations (Gonçalves, 2011). For this, investment in capacity building aimed at improving the performance of organisations is necessary, as captured in the balancing loop – *pressure impact on capacity* (B10). Sopha and Asih (2018), Anjomshoae *et al.* (2017), Obaze (2019) and Stewart and Ivanov (2019) addressed productivity and performance management.

4. Discussion and research agenda

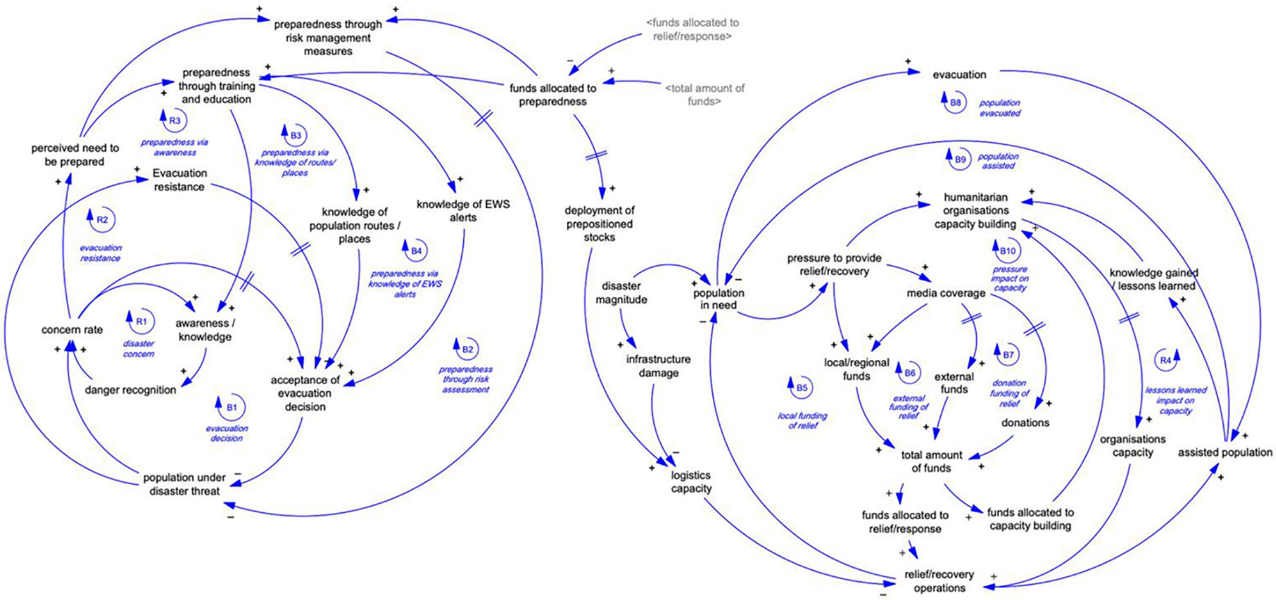
In this section, we discuss our findings and directions for future research. From the sample of 88 papers, 6 presented conceptual models only and 12 presented CLDs (two papers presented only CLDs and the others presented CLDs together with conceptual models), explaining the major relationships in

Table 3 Services in HO references

Services in HO	References
Housing recovery	Diaz *et al.* (2015, 2019), Kumar *et al.* (2015), Lawrence *et al.* (2022)
Debris management	Kim *et al.* (2018), Ramezankhani and Najafiyazdi (2008), Magalhães *et al.* (2020)
Power companies and energy services	Hernantes *et al.* (2013), Powell *et al.* (2016), Armenia *et al.* (2018)
Information and communication services	Suarez (2015), Hiltz *et al.* (2013), Diedrichs *et al.* (2016), Han *et al.* (2008), Zhong (2018)
Healthcare services	Ager *et al.* (2015), Arboleda *et al.* (2007), Babaei and Shahanaghi (2018), Su and Jin (2008), Khanmohammadi *et al.* (2018), Powell *et al.* (2018), Li *et al.* (2019), Xu *et al.* (2015), Voyer *et al.* (2016), Erkayman *et al.* (2022), Gonçalves *et al.* (2022), Rong *et al.* (2022), Van Oorschot *et al.* (2022)
Shortages of facility services in residential, commercial and industrial facilities	Hwang *et al.* (2015, 2016)
Interactions across multiple service sectors	Santella *et al.* (2009), Hernantes *et al.* (2013), Song *et al.* (2018)

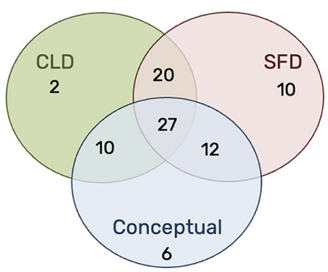
Source: Table created by Authors

Figure 9 Causal structure for pre- and post-disaster operationsNote: Shadow variables (duplicate variables) are captured between those greater and lower than the signs in grey



Notes: Shadow variables (duplicate variables) are captured between those greater and lower than the signs in grey
Source: Figure created by Authors

Figure 10 Venn diagram with articles containing a conceptual model, CLD or SFD



Source: Figure created by Authors

HO settings (see Figure 10). These 18 studies suggested the development of an SFD model for future research. Another 47 papers presented both CLDs and SFD models, 10 presented only SFD models and 12 presented both conceptual and SFD models. These papers discuss limitations and suggest model improvements for future research, including the application to other cases to enhance the generalisability and comparability of the results. Therefore, the improvement of previously developed models and the application of models to different cases (multi-case studies) to enhance the generalisability and comparability of the results are suggested as a research agenda. Finally, one paper does not present a conceptual model, CLD or SFD.

Delays and their representation are key concerns in model development. Kumar *et al.* (2015) mentioned the importance of the awareness of delays and flexibility in work schedules in policy design. Berariu *et al.* (2016b) and Besiou *et al.* (2011, 2014) focused on the delays expected due to infrastructure damage at the post-disaster stage. Gonçalves (2011) mentions human resource hiring and personnel training delays as challenges for humanitarian organisations to scale up their operations. The need to study the scalability of operations represents a gap in the literature. Powell *et al.* (2016) observed that their example of risk identification and assessment of flood preparedness was compact and limited; however, the methods were scalable to more extensive systems (e.g. large-scale floods). The development or adjustment of models with a greater focus on expected delays is a contribution to the research agenda.

To deepen our analysis, we adapt the clusters proposed by Behl and Dutta (2019) to identify gaps in the adoption of SD:

- Review papers;
- Theoretical and case-study studies;
- Classification with respect to phases of disaster;
- Studies covering HL and HSC;
- Performance evaluation;
- Resilience studies;
- Information technology (IT) studies; and
- Big data analytics studies.

4.1 Review papers

Three of the articles in our sample were reviews. Cunha *et al.* (2021) review the effects of disasters on migration. Besiou and Van Wassenhove (2021) reviewed the extant literature in the *JHLSCM* journal using SD in HO. Mishra *et al.* (2019) reviewed the application of simulation techniques (e.g. Monte Carlo, discrete-event, agent-based and SD simulations) in disaster management literature. These reviews provide policy implications and lessons learned from past recovery cases that can inform policy design for future disasters. Despite such insights, these reviews failed to reveal the characteristics that render specific policies adequate for facing different disasters. Therefore, a review of the implications and lessons learned for policies establishing delivery supplies to affected areas (e.g. trade-offs between cost and time prioritisation and short- and long-term relief and recovery operations policies) is suggested as a research opportunity.

4.2 Theoretical and case study studies

Despite the number of case study papers (85 out of 88 papers presented in Table 1), only a few have developed multi-case research. Multicase studies enable cross-case analysis and lead to more generalisable insights; thus, they are essential for developing more meaningful and applicable CLDs and SFDs. The loops presented in those CLDs and SFDs can capture rich and nuanced interactions among different stakeholders and can be used by decision-makers responding to different types of disasters (e.g. sudden-onset, slow-onset, climate-related or man-made disasters). For example, during floods, an effective EWS can save lives by advising the population to evacuate to high-risk areas. By contrast, during migratory movements due to political crises, EWS serve no purpose because decision makers do not trigger alerts. In such settings, an evacuation is initiated with safety concerns that may slowly increase, and once it crosses a threshold, it leads to an evacuation decision. The development of multi-case studies for cross-case analyses and case studies with interactions among different stakeholders are highlighted as research paths.

4.3 Classification with respect to phases of disaster

The distinction between disaster phases was evident among the studies, directing us to develop a CLD with pre- and post-disaster distinctions. Berariu *et al.* (2016a, 2016b) considered the flood response as an example. Diaz *et al.* (2015, 2019) considered housing recovery after catastrophes. Hwang *et al.* (2015) studied post-disaster facility restoration. In contrast to these articles, da Silva *et al.* (2020) researched EWS, and Ahmad and Simonovic (2001) and Simonovic and Ahmad (2005) discussed human behaviour and evacuation planning before a disaster occurs. Therefore, a summary of different disasters and their phases, considerations, consequences, policies and implications for general CLD provides an opportunity for future research. Although the distinction between pre-and post-disaster was evident in the sample, little was known about the intersection of the pre- and post-disaster stages. Therefore, for future research, we propose deepening topics that permeate the pre- and post-disaster stages (e.g. allocation of funds for disaster preparedness and response).

4.4 Studies covering humanitarian logistics and humanitarian supply chains

According to Behl and Dutta (2019), HL research has the most important discussion on inventory management, procurement, transportation, warehousing, distribution, agility, sustainability-related studies, stakeholders and coordination-related studies. Despite the range of topics covered by this cluster, several research opportunities remain. Lawrence *et al.* (2022) raised awareness of the logistical challenges at the node legs of supply chain connections and the need for synchronisation to ensure an efficient, agile and continuous flow of materials in and out of the disaster zone.

Santella *et al.* (2009), Uddin *et al.* (2018) and Allahi *et al.* (2021) shed light on research opportunities related to disaster-affected population migration (e.g. management of shelters used by the displaced population and analysis of available routes to leave the affected area). Allahi *et al.* (2021) showed that the lack of support from the HO during refugee crises can seriously impact migrant health and education. Uddin *et al.* (2018) believed that their research could be used as a basis for designing future research to understand shelter dynamics and their effective contribution to disaster emergency response. Kosmas *et al.* (2022) were the first to apply SD in SAR operations linked to migration by sea (MBS). SAR operations (e.g. resource and asset logistics, the role of volunteering to provide the necessary support to experts, management of mixed fleets that can be used) and MBS (e.g. arrival and disembarkation processes at ports, onwards migration journeys, return migration to the country of origin, the role of humanitarian organisations in short-and long-term actions and cooperation between stakeholders at land and sea) are highlighted as research opportunities.

However, while most of the research is related to sudden-onset disasters (e.g. earthquakes, floods and hurricanes), there are opportunities for further research referring to slow-onset disasters (e.g. famine, poverty and refugee crises) and, consequently, development programmes. Thus, humanitarian organisational development programmes are recommended as research paths. In this context, another opportunity for future research is the dependency resulting from humanitarian aid. Gonçalves (2011) pointed out that disaster relief may unintentionally lead to dependency. For example, Sodhi and Knuckles (2021) conducted a field study and concluded that funding, although crucial for reducing deprivation in the short term, may increase dependence on humanitarian aid rather than reduce it. The dependency theme is also closely related to the sustainability of operations because long-term development programmes require cost-efficient procurement, which may make sustainable interventions difficult (Besiou *et al.*, 2021). Some studies investigating the impact of material convergence (i.e. unsolicited donations) have also touched upon the issue of sustainability in HO. Nevertheless, there is ample opportunity for further research focusing on sustainability, such as the close relationship between HO and the United Nations Sustainable Development Goals (Besiou *et al.*, 2021), reverse logistics of unused medical resources, fleets, generators, containers and equipment useful for future relief and recovery operations.

4.5 Resilience studies

Community resilience and authorities' efforts to manage disasters before and after a disaster dictate the severity of the damage (Diaz *et al.*, 2015). Anagnostou *et al.* (2016) used SD modelling to analyse the behaviour of interactions between disaster preparedness, environmental instability and resilience in a logistics and supply chain network. Relationships such as "the more prepared, the more resilient" and "increased disaster awareness and preparedness increases resilience" are demonstrated. Ager *et al.* (2015) examined the resilience of health systems, whereas Feofilovs *et al.* (2020) focused on community resilience to floods. Gotangco *et al.* (2014)

integrated the physical, social, economic and organisational sectors into a system resilience model that can serve as a government decision-support tool. Harpring *et al.* (2021) argued that supply chain resilience is directly affected by the quality of infrastructure before a disaster. While several studies have focused on resilience, the analysis of strategies adopted by different actors to build resilience and the factors contributing to making distinct populations resilient to different disaster types needs to be addressed.

4.6 Performance evaluation

In areas where SD simulation relies on performance-guiding policies and can be used for evaluating the performance of systems (Mishra *et al.*, 2019), Peng *et al.* (2014a) compared the system performance of eight scenarios based on different assumptions (e.g. delay, demand forecasting, information sharing, inventory planning strategies and transport) and Heaslip *et al.* (2012) focused on procedures to improve the performance of stakeholder cooperation. Nevertheless, da Silva *et al.* (2020) indicated that further research should focus on disaster management performance and measurements. Without measuring performance in terms of effectiveness, it is difficult to understand the current practices and promote improvements (Lettieri *et al.*, 2009; da Silva *et al.*, 2020). Therefore, we suggest mapping policies simulated for different cases (disaster and operation types) based on productivity and performance. Targeting the productivity and performance of humanitarian organisations, Kosmas *et al.* (2022) suggest further research examining humanitarian organisations' resource use (e.g. in terms of area coverage and dollars per life saved) by using historical data.

4.7 Information technology-related studies

Recently, several technological innovations have been introduced to improve the efficiency and effectiveness of HO systems. The adoption of further innovations is expected to grow, requiring humanitarian professionals to update their operations and skillsets (Besiou and Van Wassenhove, 2020). Hiltz *et al.* (2013) identify research gaps when investigating the roles of information, technology and communication systems in the context of disasters. While it is difficult to quantify and easy to underestimate, the effect of communication can play an important role in disaster response. In this regard, quantifying the effects of information, technology and communication systems in HO is suggested as a research agenda. Diedrichs *et al.* (2016) first attempted to quantify the impact of communication on the number of lives saved and the amount of dollars spent. Lawrence *et al.* (2022) highlighted the need to track and trace relief items to accelerate delivery. One way to track and trace disasters is through a quick response code that can be used offline in disaster situations.

Other studies have discussed the use of interactive games to inform decision-making during disasters. Suarez (2015) and Harke and Leeuw (2015) stated that playable SD models can immerse participants (scholars and practitioners) in intensive, interactive experiences that accelerate learning. Shi *et al.* (2021) used game theory across disaster phases such as mitigation, preparedness and response. However, this research lacks an understanding of the interactions and game relationships between (and within) the government and its beneficiaries. Significant advancements could be made by delving into the behavioural interactions between residents and local governments from a dynamic perspective. Thus, the creation of user-friendly mobile interface systems and platforms (e.g. teaching and explaining disaster risks, asking for help and receiving alerts) and the development of games for interactive learning (e.g. evacuation planning, humanitarian organisation management in the face of development programmes and allocating donations) are highlighted as research opportunities.

4.8 Big data analytics studies

In addition to technology-related opportunities, big data has been studied in HSCM (Behl and Dutta, 2019). Big data analytics can summarise disaster data, predict future trends and evaluate different scenarios to prescribe possible outcomes (Lawrence *et al.*, 2022). The data used in academic research are primarily from case studies. However, social media, geographic information systems-based data and Google Analytics data offer additional opportunities for research. Lawrence *et al.* (2022) discuss the possibility of using digital platforms for crowdsourcing. Han *et al.* (2008) discussed the importance of real-time scene information for disaster relief commanders. Timely and accurate transmission of information and objective reporting of truth through the media can significantly enhance relief efforts (Han *et al.*, 2008). Suarez (2015) used geo-information to support humanitarian decisions.

However, collecting data for model development and calibration remains challenging. As the frequency of disasters increases, humanitarian organisations have recognised the crucial role of disaster-related data in mitigating their impact (Kim *et al.*, 2018). Favereau *et al.* (2020) articulated the need for information availability, parameter adjustment, variables and events to generate new scenarios in evacuation decisions during disasters. Gotangco *et al.* (2014) suggest that future work on their model should be concerned primarily with replacing dummy variables with actual values based on historical data. Guo and Kapucu (2019) also showed that data were limited, and the contingency plans of their model did not cover all stakeholders (e.g. volunteer organisations) in the potential disaster response. Similarly, Diaz *et al.* (2015) suggested that further research should use actual data for their model's experiments and serve as a solid background for future predictions in the context of housing recovery. These examples highlight the challenges of obtaining adequate data to inform and test model development in various contexts (Hernantes *et al.*, 2013; Hiltz *et al.*, 2013; Kumar *et al.*, 2015). Therefore, big data methods and processes for collecting HO data should be adopted in future studies.

5. Conclusion

Although HO have experienced a surge in academic interest, further research is required to mitigate, better prepare for, respond to and recover from hazardous events. This SLR of the HOM literature not only recognises important topics already studied but also identifies the need for HOM to guide future academic and practitioner research. It identified 88 papers published between 2001 and December 2022, capturing the complex dynamic relationships of operations in humanitarian settings. By analysing the selected papers, we mapped the topics studied in the extant literature, defined a list of literature topics (taxonomy) and connected the main variables identified by these studies to a comprehensive CLD.

Table 2 provided a taxonomy of topics and variables from the selected literature focusing on the pre- and post-disaster stages of the CLD. The comprehensive CLD presented in Figure 9 mapped the inter-relationships among the variables identified in the SLR. The taxonomy and the comprehensive CLD answer the first research question, "Which topics in HOM drive SD simulation modelling research?", shedding light on HOM topics using SD modelling.

CLDs capture qualitative relationships, providing significant insights into the interconnections among variables and allowing researchers to better develop dynamic hypotheses. However, these dynamic hypotheses can only be tested using formal SD simulation models. A formal SD simulation model is required to quantitatively confirm and validate the cause-and-effect relationships across variables. Moreover, future studies could focus on distinguishing key variables and feedback structures according to the disaster type.

Academic researchers could use the proposed CLD to strengthen the following:

- Pre-disaster descriptive case studies that include migratory movement around the globe, evacuation decision-making, knowledge of population routes and evacuation processes.
- Post-disaster descriptive case studies, such as the impact of donations and last-mile distribution in the populations most affected in a pandemic scenario.
- Analysis of hypothesised causal influences (which can evolve into theory building) and relationships using mental models that communicate detailed disaster and humanitarian crises.

To respond to the second research question, "What are the gaps and opportunities in SD application in HO extant literature?", we analysed the papers from our SLR according to the clusters proposed by Behl and Dutta (2019) and systematically considered opportunities for further research, which led to the development of the discussion section and research agenda. Each category ends with a brief statement on its contribution to the research agenda, which serves as a guide for advancing HOM studies through SD.

Our research contributes to the HOM academic literature by looking back at those publications, analysing their content, capturing isolated variables and representing the intrinsic relationship among such variables through a comprehensive CLD. Our analysis and synthesis generated several insights for future research opportunities and guidance for improved disaster management. Thus, for academics, we present a taxonomy, CLD and research agenda. For policymakers and funding agencies, these insights emphasise the need for prevention and alternative funding mechanisms that can lead to better disaster management. We believe that these opportunities will boost HOM research and improve decision-making in the field, leading to improved policies and more effective humanitarian responses.

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