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SIMULATION APPLICATIONS IN HUMANITARIAN LOGISTICS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Humanitarian logistics involve planning, acting and controlling situations in which vulnerable people are involved. Simulation techniques can successfully represent the dynamics of disasters, characterized by situations of complexity and uncertainties. This work aims to review papers that apply simulation techniques to solve problems that arise in disaster situations. To accomplish this, we analysed 33 papers published from 2010 to 2019, indexed in Scopus or Web of Science databases, that used simulation techniques to solve humanitarian problems. The descriptive analysis conducted found out that there is a small but increasing number of papers over time. Discrete events simulation and system dynamics are the most used techniques. From the content analysis we find that most research focuses on short term decisions and solving problems related to post-disaster response in unforeseen events. However, topics such as evacuation and transportation of victims are still unexplored.

1 INTRODUCTION

Disasters cause situations of social, economic, and political uncertainty. When a disaster occurs, the goal of organizations and authorities is to help the victims. This help is of vital importance, because many lives depend on it. In these situations, quickly find an efficient way to help people can make a big difference.

Disasters can be natural as earthquakes or man-made as armed conflicts, economic crises, and others (Van Wassenhove 2006). They can happen slowly or suddenly. Now, more frequently, sudden natural disasters happen, due to disordered urban growth and climate change. According to the Center for Research on the Epidemiology of Disasters, in the years 2004 to 2013, natural disasters have killed an annual average of 99,820 people, and 199.2 million people are victims worldwide. Economic damage caused by natural disasters was estimated at a ten-year annual average of US$ 162.5 billion (Guha-Sapir et al. 2015).

Optimization and simulation are the major tools to address and overcome logistics challenges. Simulation in the area of humanitarian logistics is a methodology that is not yet widely used in comparison with others from operations research (OR). Still the dynamic technological development in simulation techniques is making its application grows in this area too.

In the humanitarian logistics literature, the paper of Hoyos et al. (2015) stands out. It provides a review of the literature on stochastic operations research models, with a focus on the techniques used for the solution, but literature reviews dedicated to the specific simulation method were not found.

For all the above, this work aims to examine the literature that applies simulation modeling to improve logistics operations management in disasters. In this sense, five research questions were formulated:

RQ1 Which types of disaster were addressed?
RQ2 Which life cycle stages of disaster were addressed?
RQ3 Which simulation techniques were applied?
RQ4 Which decision levels were addressed?
RQ5 How important is the use of simulation?

This paper is organized into six sections. The second section presents a theoretical framework. The third section presents the methodological approach. We follow with the results and discussions sections. In the final section, we present the main conclusions.

2 BACKGROUND

Humanitarian logistics correspond to the processes of planning, implementing and controlling the efficient, cost effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. Some differences between the business logistic and humanitarian are the need for flexibility to overcome unexpected situations and the uncertainty of demand, even in the long term (Van Wassenhove 2006).

The framework adopted by Leiras et al. (2014) was adapted to classify the papers for this study. As the present study only refers to papers that use simulation, the categories problem type, optimization type, and coordination perspective do not apply. The categories used in this work are presented below:

- General paper information: journal title, publication year, authors and countries of affiliation.
- Disaster type: disasters were divided into natural or man-maid. Both can also be are classified as sudden-onset or slow-onset. Natural sudden-onset concerns to earthquakes or tsunamis, for instance. While terrorist attacks are examples of man-made sudden-onset. Natural slow-onset disasters consider situations of famine and drought. Man-made slow-onset includes political and refugees crisis (Van Wassenhove 2006).
- Disaster life cycle stage: it is divided into mitigation, preparedness, response, and recovery. Mitigation and preparedness are different because mitigation corresponds to the measure of risk and reduction of the onset of a disaster by authorities; while the second, concerns to training and methods to quickly respond to disasters. Response are the actions taken to try to maintain the physical and social structure of the community. Recovery are the procedures that seeks to stabilize the community in the long term, after the disaster (Altay and Green 2006).
- Research method: two categories were considered. Simulation techniques papers are inside the analytical researches category, according to Natarajarathinam et al. (2009). Analytical papers can be empirical or applied. Empirical researches evaluate collected data or observations. Applied researches are the ones that contain case studies or interviews.
- Geographical perspective: the location of the analyzed area used in the case study papers.
- Decision level: the papers are divided into strategic, tactical and operational. Strategic decisions are those that have a planning horizon of more than one year, that is, long-term decisions. Tactical and operational levels present, respectively, medium and short-term decisions (Ballou 2004).
- Stakeholder perspective: we divide into government, organizations (private or non-profit) and victims. The papers were fitted according to the users for which the solution was designed.

3 RESEARCH METHOD

A systematic literature review means to identify, evaluate and interpret all available research relevant of an area (Kitchenham 2004). According to Seuring and Gold (2012) and Carvalho et al. (2013) a systematic review includes a descriptive, a bibliometric and a content analysis. A combination of bibliometric study and content analysis allows the identification of the most important topics, approaches, and methods, as

well as the most important definitions of the theme (Carvalho et al. 2013). The phases of the systematic review developed in this research are summarized in the Figure 1.

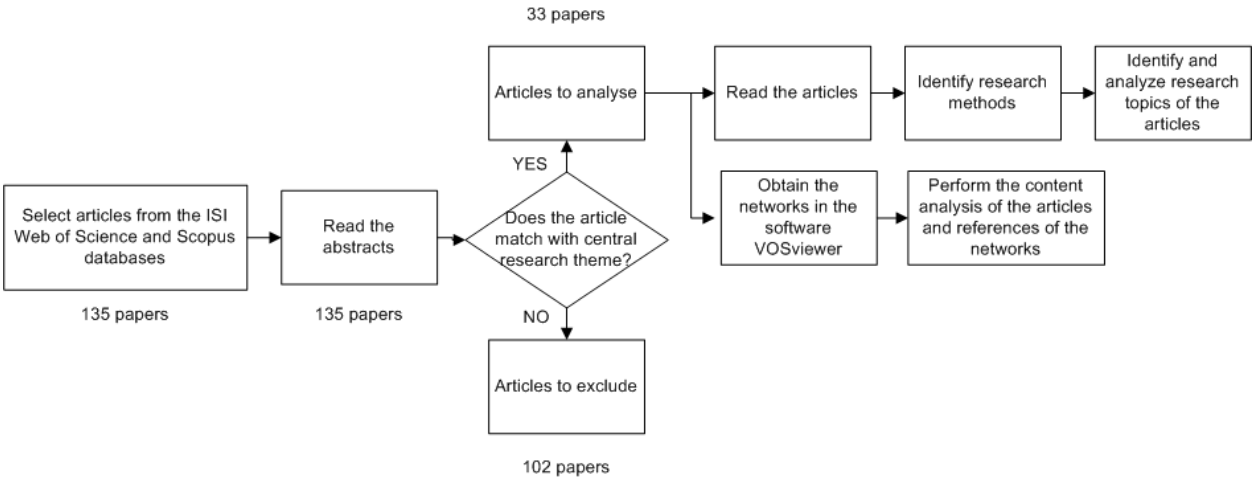

Figure 1: Phases of the systematic review.

The papers were collected from Web of Science and Scopus databases. It includes papers written in English. For this literature review, only papers published in the last decade (2010-2019) were considered. The keywords used to search were: "humanitarian logistics" or "humanitarian supply chain" or "humanitarian relief chain" or "humanitarian chain". After the first review we included "disaster relief humanitarian" or "disaster relief logistics". Keywords such as "simulation" or "system dynamics" or "agent-based simulation" were used to specify the techniques inside the main topic of study. We considered the filters "Article" and "Proceedings paper" as "Document Types" during the search.

The search resulted in 111 papers from the Web of Science and 134 papers from the Scopus database. A sample of 135 papers was analyzed, after the removing of duplicates. To define the sample, two criteria were considered. The first exclusion criterion concerns the use of humanitarian logistics to solve healthcare problems. The second exclusion criterion was the use simulation techniques. After this sorting process, 33 papers constitute the selected sample for the next phases of the systematic review.

4 RESULTS

4.1 Descriptive Analysis

For this analysis, the 33 selected papers were evaluated, of which three are conference papers. Was Wassenhove, Luk N.V. was identified as the author with the higheest amount of publications in the area of humanitarian logistics in which simulation is applied (3 papers, 9.1%). It is also possible to identify International Journal of Humanitarian Logistics and Supply Chain Management (6 papers, 18.2%) as the top source of publication of works related to the topic.

Figure 2 presents the distribution of the papers published per year. Despite some fluctuations, it is possible to appreciate the constant increase in research related to humanitarian logistics and simulation. It is thus confirming a recent relevance of the topic. The majority of papers 66.7% address to natural sudden-onset disasters. Two papers analyzed more than one disaster type and both were applied to natural and man-made sudden-onset disaster. From 2013 to 2019, in average, four publications per year use simulation techniques and humanitarian logistics. It helps answer the (**RQ1**), presenting the number of papers of each disaster type, according to its publication year. We can notice the predominance of natural sudden-onset disasters, followed by papers that not specified the disaster addressed.

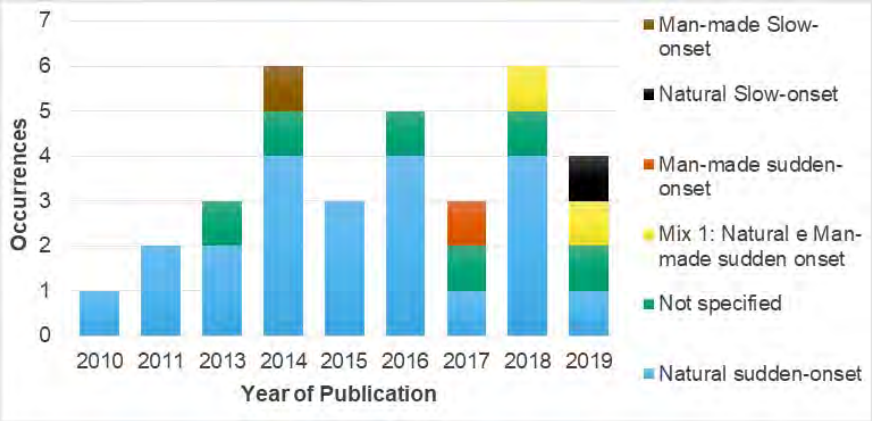

Figure 2: Publications by year according to disaster type classification.

In Figure 3, note that the response stage is present almost every year, and this stage has the highest number of occurrences over the years (63.6%). Preparedness was the second more studied stage, and represents 9.1% of the sample. Five papers included more than one disaster stage in its content. They included preparedness and response simultaneously. These information answer the (**RQ2**) and is consistent with other literature reviews on humanitarian logistics (Leiras et al. 2014).

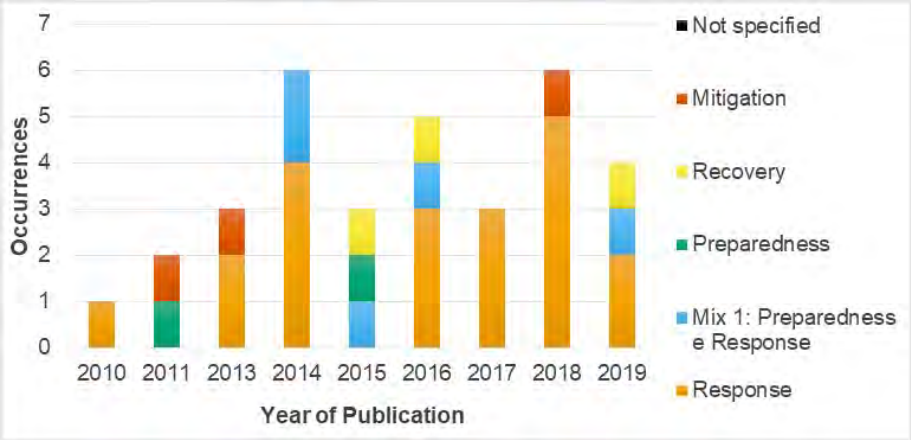

Figure 3: Publications by year according to disaster life cycle stage.

System dynamics (SD) and simulation optimization (SO) were the techniques most applied to papers of natural sudden-onset disasters. For the other classification of disaster type, the agent-based simulation (ABS) was highlighted the method. The distribution of simulation techniques by disaster type is presented in Figure 4. The hybrid simulation is a concept used by Balcik and Krejci (2015) to describe the methodology of a paper that uses discrete-event simulation (DES) allied to ABS to create an approach to humanitarian logistics. It was verified in three of the selected papers. Concerning to research question (**RQ3**), the use of SD and ABS highlights, compared to the other techniques, with ten and nine publications each.

Figure 5 shows the occurrences of disaster stages to each disaster type. Crossing the information of disaster life cycle stages and disaster types, it is possible to note that the primary use of simulation was to conceive solutions to respond and prepare for disaster. Six papers did not define the disaster type for which apply, and all these papers use empirical analytical research method.

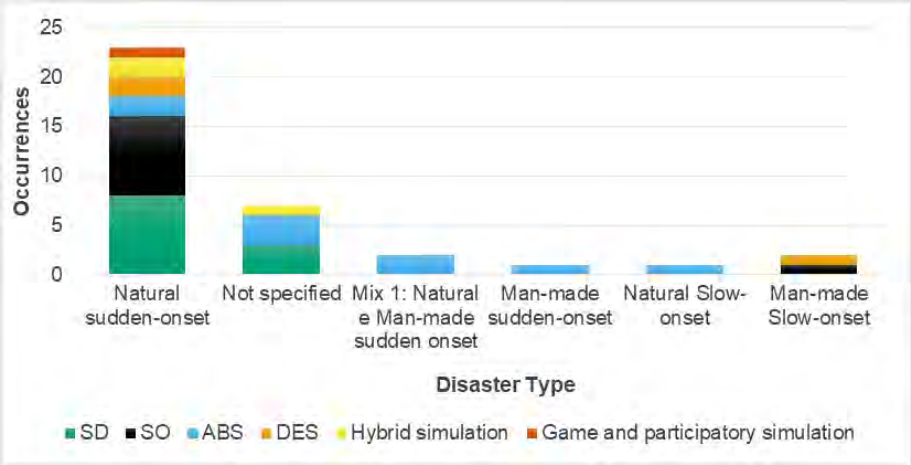

Figure 4: Simulation techniques applied to each disaster type.

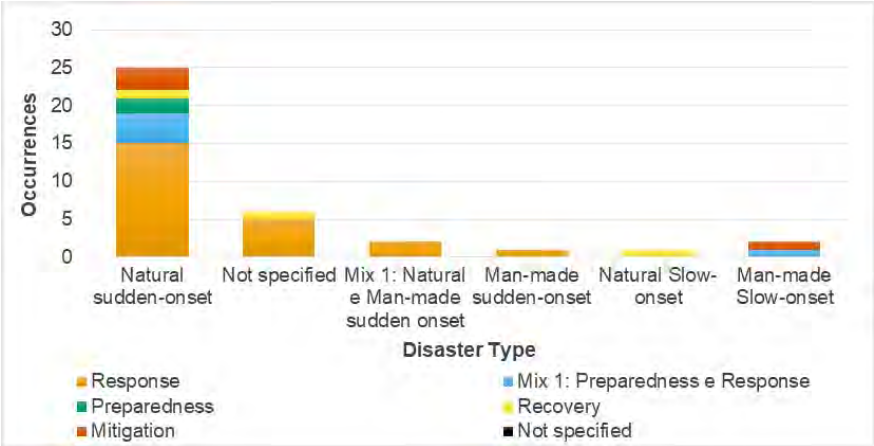

Figure 5: Paper occurrences of some disaster stage for each disaster type.

When we examine the techniques applied and life cycle stages simultaneously, no pattern can be defined. SD is more present in response stage. ABS is applied to response and recovery stages, while SO is applied to response and mitigation stages. This result is shown in Figure 6.

We also crossed information about the technique applied and the decision level and it is presented in Figure 7. Answering the research question (**RQ4**), the operational decisions were the most applied in the sample, followed by tactical and strategic ones. Papers with operational decisions often apply ABS and SD, whereas papers with strategical decisions mostly apply SO. Tactical level decisions present a more uniform distribution of simulation technique employed. However, to this decision level, there is a small number of publications per technique.

4.2 Bibliometric Analysis

4.2.1 The Keyword Network

The keyword network was used to identify concepts associated with humanitarian logistics and simulation. This network includes keywords that have at least two co-occurrences. One publication in which two keywords occur together in the title, abstract, or keyword list counts as co-occurrence of two keywords.

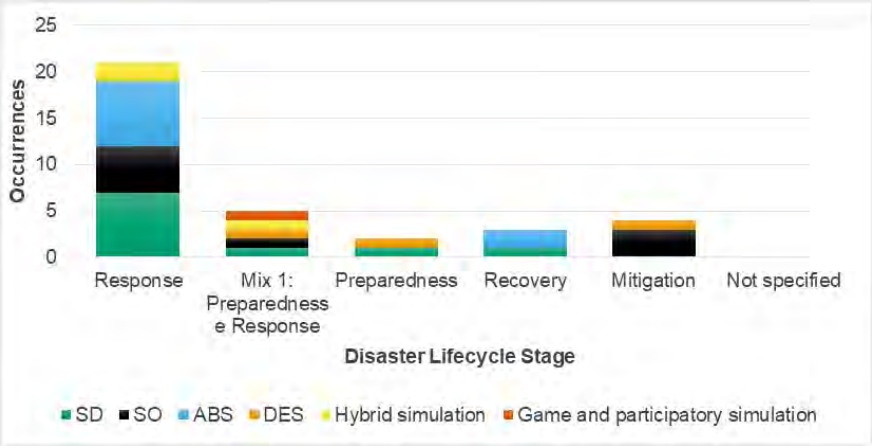

Figure 6: Simulation techniques applied to each disaster life cycle stage.

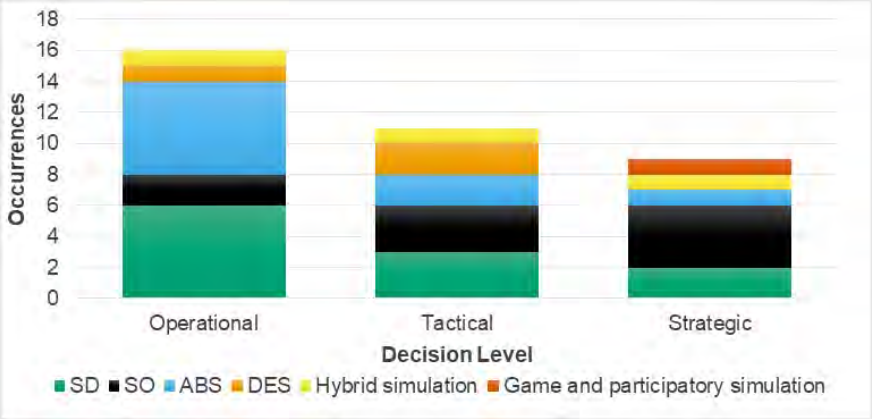

Figure 7: Occurrence of simulation techniques for papers according to their decision level.

This analysis reveals main connections between humanitarian logistics and supply chain management, humanitarian logistics and emergency services, disaster prevention and emergency services, and simulation and emergency services (Figure 8).

The keyword "emergency services" is highlighted by this analysis and it is consistent with the **RQ2** response, i.e. the papers are mainly concerned with the response stage. This network classified the keywords into three clusters of the most representative keywords for this work. The green cluster presents keywords directly related to the term "humanitarian logistics," the blue cluster is made up of keywords associated with the word "management," and the red cluster gathers keywords related to the word "disaster."

4.2.2 The Co-citation Network

The co-citation network can reveal the common interest of research groups. It shows references cited by the papers of the sample. To be included in the co-citations network an author had to be cited by five papers. The size of the node is proportional to the frequency of a cited reference author.

This analysis also defines three clusters (Figure 9). The cluster illustrated in green is composed of authors that explore the concept of humanitarian logistics. The blue cluster presents authors that work with simulation techniques. Finally, the red cluster shows authors of operational research and simulation papers, mostly with stochastic problems.

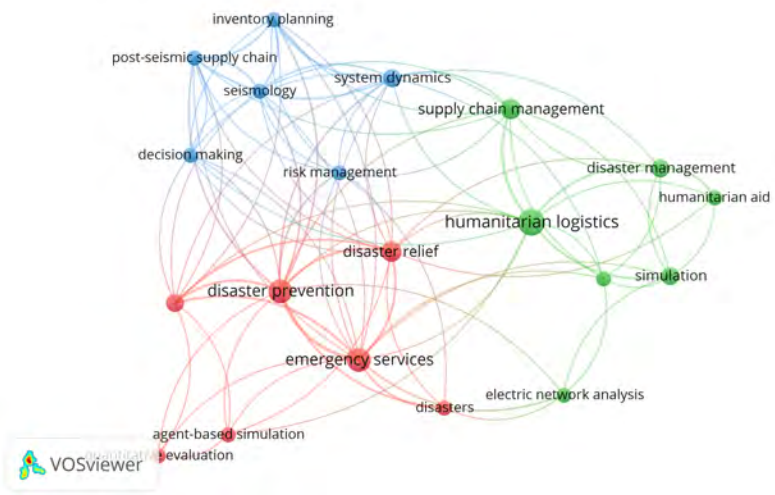

Figure 8: Keyword network.

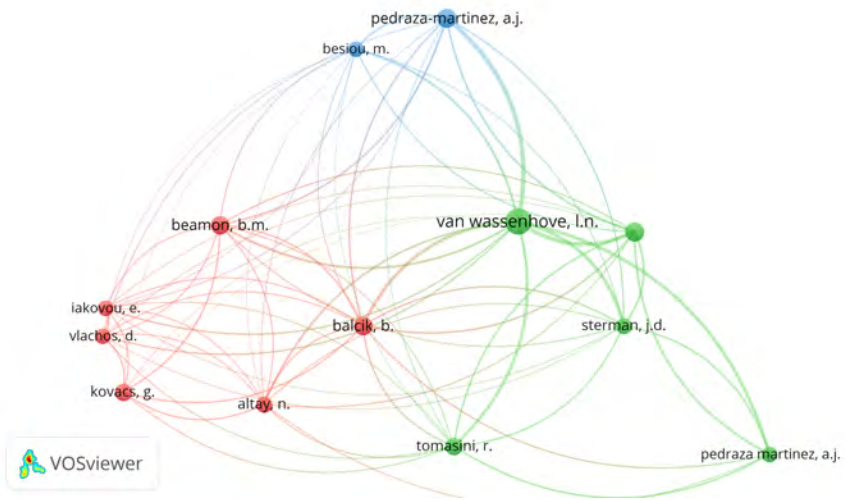

Figure 9: Co-citation network.

4.3 Content Analysis

In this analysis, the 33 papers are classified according to the simulation methodology presented.

4.3.1 Discrete-event Simulation

The DES approach was used by Mohan et al. (2013) to improve the efficiency and productivity of a food recovery center that plays the central role of purchasing and assembling food for distribution. The city of Pikini, Senegal, was studied by Green et al. (2013). They determined whether emptying latrines in a flood-prone urban slum would be a sustainable business for the local population and profitable for the private sector. Iakovou et al. (2014) created a methodology that quantifies the impacts of risk mitigation strategies on the humanitarian logistics supply chain. D'Uffizi et al. (2015) used DES to help to plan different action strategies to be applied by rescue teams in emergency and risk situations.

4.3.2 System Dynamics

Besiou et al. (2011) illustrates the adequacy of the SD methodology as a tool for decision-makers to understand the effect of their decisions on humanitarian operations. They analyze field vehicle fleet management and find that the SD can accurately represent the dynamic complexity of humanitarian operations and is, therefore, an appropriate tool for studying these systems. Peng et al. (2014a) introduce two uncertain factors (information delay and road condition) to analyze the effectiveness of response actions in a post-seismic disaster. To validate the model, the authors use data from the 2008 Wenchuan earthquake. Kunz et al. (2014) modeled the delivery of therapeutic feed items ready for use during a phase of immediate response to a disaster and analyze the performance of different preparation scenarios. Besiou et al. (2014) applied SD to model vehicle supply chains (VSCs), incorporating three different structures of VSCs that International Humanitarian Organizations operate. Peng et al. (2014b) simulated variables to predict the post-seismic road network and analyze the behavior of the relief supply chain in the event of an interrupted disaster.

Diaz et al. (2015) propose improvements in building materials inventory management in a post-disaster perspective. They use theoretical data to simulate the reconstruction of houses considering scenarios with different time periods until the adjustment of the stock level. An alternative disaster management model for East Java was created by Octavia et al. (2016), to reduce the response time to recurring natural disasters in the region. They suggest to include a non-governmental organization to assist in the critical operations raised, as current there is only government data. Diedrichs et al. (2016) present a discrete model of mathematical SD to study the role of communication and logistical coordination between actors in an emergency disaster response operation. They measure its impact on the number of lives saved and cost.

Berariu et al. (2016) present a model that allows simulating the deployment of resources to meet the growing needs of products, such as food and other consumables, during disaster situations. The focus is on managing a suddenly increased demand for an affected population under restricted transport conditions. Of all papers selected of SD, only the paper of (Octavia et al. 2016) is applied to a case study. The remaining papers focus on creating a tool that can be replicated in cases of similar disasters, either to mitigation, preparedness or response stages.Yorvarak et al. (2017) aim to optimize the supply water of disaster relief, they modeled the disaster relief logistics network using similarity to the electrical circuit.

4.3.3 Agent-based Simulation

Altay and Pal (2014) present the importance of information exchange and the role of cluster leaders to encourage a better information flow. The application of ABS showed that clusters, if used properly, encourage a better information flow and facilitate the effective response to disasters. The process of donating, receiving, and allocating goods was modeled by Suárez Moreno et al. (2016). They presented insights for coordinating donations between warehouses in a post-disaster situation. Ochoa et al. (2017) uses an agent-based approach to model and simulate dynamic human crowds, but introduces the use of specific anthropometric and socio-cultural aspects that impact individual and group behavior.

Aros and Gibbons (2018) studied the effect of using different forms of communication between organizations on the response time to occurrences. Liu and Suzuki (2018) analyzes the effect of information exchange on relief goods supply chains, in order to evaluate the effect of the regional BCP (Bussines Continuity Plans) on disaster response. A prototype was generated by Wang and Zhang (2019), to check the gap between demand and supply in areas affected by disasters, given a limited time window. They used the case of the earthquake in Sichuan province to validate the model. Abualkhair et al. (2020) consider strategies for managing spontaneous volunteers in disaster relief centers affected by the convergence of volunteers and materials. Gore et al. (2019) to characterize the well-being of newcomers (i.e., refugees seeking asylum) in the context of asylum logistics using Schwartz's theory of values.

4.3.4 Hybrid Simulation

Hybrid modeling is the combination of various simulation techniques described above (Thomé et al. 2016). The analysis performed by Cohen et al. (2013) examines both the success in the transport of aid (performance model) and the success in affecting the satisfaction of the population (model of population behavior). The models were created using DES and SD, respectively.

Balcik and Krejci (2015) present a conceptual framework for a model to be used to study decision-making and the behaviors of humanitarian logistics actors. They determine if certain coordination mechanisms allow for better efficiency and effectiveness of the relief chain over time. The ABM component of the hybrid model allowed the representation of heterogeneous agents (donors, international NGOs, and local NGOs), while the DES component captured the flow of relief supplies. Widera et al. (2017) designed multiple method simulation environments for the logistical configuration of humanitarian supply chains to support the decision-making process. The distinct components (for example, suppliers or logistic centers) are represented as ABM and DES elements are used for disaster modeling and the constraints of multiple events within the procedures of a humanitarian supply chain.

4.3.5 Game and Participatory Simulation

Bruzzone et al. (2016) developed a "modeling, inter-operable simulation and serious game" simulator to help decision makers to preview and evaluate time, cost and effectiveness of actions taken in disasters that create demand by IDP (Internally Displaced Persons) and refugees.

4.3.6 Simulation Optimization

Seven papers apply SO. Stauffer et al. (2018), Dufour et al. (2018), and Ghasemi et al. (2019) apply the simulation as a tool to calculate parameters of the mathematical model, which were affected by uncertainty. Whereas, Ertem et al. (2010), Ertem and Buyurgan (2011), Swamy et al. (2017), and Fikar et al. (2018) adopt simulation techniques as tools to evaluate solutions obtained through optimization.

5 DISCUSSION

The research questions 1 to 4 are answered directly from the results presented in the previous section. To answer the **RQ5** it is necessary to access some previous researches.

Simulation is an important tool in humanitarian logistics, due to its ability to represent disaster situations and build possible scenarios. It was possible to see the use of SD and ABS linked to non-linear problems and DES applied with operations research to manage stochastic distributions, which are frequent in disaster situations, due to the complexity and uncertainty that these generate. Though these advantages, the sample of simulation papers covering humanitarian problems is small. It was also perceived by Diaz et al. (2013) and Mishra et al. (2019).

From the results, it was possible to verify that around 45.5% of the studies focus on the response stage, as on natural sudden-onset disasters. Few works were found focusing on slow-onset disasters. This occurrence may indicate a scope of use of these techniques. The authors usually justify the choice of these techniques by the ease of inserting complexity, stochastic parameters and representing the decision making process. However, it is not clear from this study whether other types of disasters are widely studied; nor is a comparison made between the frequency of application of simulation techniques and other methods of solving similar problems. Just as Leiras et al. (2014) points out, drought, and disease epidemics can cause long time damage to huge populations and simulation techniques are appropriate tools help with these problems. Another overlooked topic was inventory management of distribution or local relief centers. These problems can be successfully addressed with simulation techniques. Also, research has been limited to the organizations and government perspective.

The application of simulation techniques is mainly present in the response stage. This result was also verified in the works done by Leiras et al. (2014) and Mishra et al. (2019). The use of simulation techniques as training tools to analyze hypothetical situations and to analyze the impact of decisions with easy parameter changes, makes this tool useful at all stages of the disaster life cycle. The formation of task forces to act in disaster situations may justify further exploration of preparedness and response stages. While, the recovery stage requires continued attention to disaster cases and mitigation requires historic data and forecast for further studies exploring these situations.

The charts presented in Descriptive Analysis and Content Analysis sections give us insights about the technique applied and decision level; however, it is not clear if the variables analyzed are related. We hypothesize some exogenous characteristics that can contribute to these results. For instance, the techniques applied can be biased by the interest or knowledge of the authors; the problem definition (stage and type of disaster) can be biased by the region (city or country) where the researchers live; or, the contact of research groups with certain NGOs may lead to studies focusing on regions where these NGOs are present. Despite the insights provided by the information gathered, it is not possible to reach conclusions only with the sample analyzed. It would be necessary to evaluate the literature on humanitarian logistics in order to fully understand the differential presented by the application of simulation in this area of research.

6 CONCLUSION

The systematic literature review in this article consists of three parts: descriptive, bibliometric, and content. After searching keywords in two relevant databases, 33 papers form the sample of analysis for this research. Through the distribution of papers over the years, it was possible to perceive an increase in the number of researches containing humanitarian logistics and simulation techniques, thus confirming the current relevance of the topic.

From the descriptive and bibliometric analyses we conclude that response, preparedness and mitigation stages were the most studied until now, respectively. It is consistent with other literature reviews about humanitarian logistics. Most part of the papers apply simulation techniques to help with natural sudden-onset disasters. However, slow-onset disaster cause major impacts in the long term if not addressed properly. A recent example is the scenario caused by COVID-19 pandemia, for which simulation becomes an useful tool to solve logistics challenges. Nevertheless, these challenges are more related to healthcare problems, a topic that was not included in our research.

System dynamics and agent-based simulation were the most applied techniques in the analyzed papers. It is possible to note that these two techniques are applied for operational decisions, while optimization simulation is more related to strategic decisions.

A limitation of this study, given its methodology, is that it is not possible to compare the performance of simulation techniques applied to similar conditions. Therefore, we can not conclude which approach is the most appropriate for each type of problem. It is a topic that can be addressed in further research.

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REFERENCES

Abualkhair, H., E. J. Lodree, and L. B. Davis. 2020. "Managing Volunteer Convergence at Disaster Relief Centers". *International Journal of Production Economics* 220:107–399.

Altay, N., and W. G. Green. 2006. "OR/MS Research in Disaster Operations Management". *European Journal Of Operational Research* 175(1):475–493.

Altay, N., and R. Pal. 2014. "Information Diffusion Among Agents: Implications for Humanitarian Operations". *Production and Operations Management* 23(6):1015–1027.

Aros, S. K., and D. E. Gibbons. 2018. "Exploring Communication Media Options in An Inter-Organizational Disaster Response Coordination Network Using Agent-Based Simulation". *European Journal of Operational Research* 269(2):451–465.

Balcik, B., and C. C. Krejci. 2015. "Hybrid Simulation Modeling for Humanitarian Relief Chain Coordination". *Journal of Humanitarian Logistics and Supply Chain Management* 5(3):325–347.

Ballou, R. H. 2004. *Business Logistics/Supply Chain Management*. 5th ed. Cleveland: Pearson Education, Inc.

Berariu, R., C. Fikar, M. Gronalt, and P. Hirsch. 2016. "Resource Deployment Under Consideration of Conflicting Needs in Times of River Floods". *Disaster Prevention and Management: An International Journal* 25(5):649–663.

Besiou, M., A. J. Pedraza-Martinez, and L. N. Van Wassenhove. 2014. "Vehicle Supply Chains in Humanitarian Operations: Decentralization, Operational Mix, and Earmarked Funding". *Production And Operations Management* 23(11):1950–1965.

Besiou, M., O. Stapleton, and L. N. Van Wassenhove. 2011. "System Dynamics for Humanitarian Operations". *Journal of Humanitarian Logistics and Supply Chain Management* 1(1):78–103.

Bruzzone, A. G., M. Massei, R. Di Matteo, M. Agresta, G. Franzinetti, and P. Porro. 2016. "Modeling, Interoperable Simulation and Serious Games as an Innovative Approach for Disaster Relief". In *The 13th International Multidisciplinary Modelling & Simulation Multiconference (I3M)*. September 26th-28th, Larnaca, Cyprus, 26-28.

Carvalho, M. M., A. Fleury, and A. P. Lopes. 2013. "An Overview of The Literature on Technology Roadmapping (TRM): Contributions and Trends". *Technological Forecasting and Social Change* 80(7):1418–1437.

Cohen, J., J. Quilenderino, J. Bubulka, and E. P. Paulo. 2013. "Linking A Throughput Simulation to a Systems Dynamics Simulation to Assess the Utility of a US Navy Foreign Humanitarian Aid Mission". *Defense & Security Analysis* 29(2):141–155.

Diaz, R., J. Behr, A. L. Toba, B. Giles, M. Ng, F. Longo, and L. Nicoletti. 2013. "Humanitarian/Emergency Logistics Models: A State of the Art Overview". In *Proceedings of the 2013 Summer Computer Simulation Conference*, 1–8. Toronto, Ontario: Society for Modeling & Simulation International.

Diaz, R., S. Kumar, and J. Behr. 2015. "Housing Recovery in the Aftermath of a Catastrophe: Material Resources Perspective". *Computers & Industrial Engineering* 81:130–139.

Diedrichs, D. R., K. Phelps, and P. A. Isihara. 2016. "Quantifying Communication Effects in Disaster Response Logistics". *Journal of Humanitarian Logistics and Supply Chain Management* 6(1):24–45.

Dufour, É., G. Laporte, J. Paquette, and M. È. Rancourt. 2018. "Logistics Service Network Design for Humanitarian Response in East Africa". *Omega* 74:1–14.

D'Uffizi, A., M. Simonetti, G. Stecca, and G. Confessore. 2015. "A Simulation Study of Logistics for Disaster Relief Operations". *Procedia CIRP* 33:157–162.

Ertem, M. A., and N. Buyurgan. 2011. "An Auction-Based Framework for Resource Allocation in Disaster Relief". *Journal of Humanitarian Logistics and Supply Chain Management* 1(2):170–188.

Ertem, M. A., N. Buyurgan, and M. D. Rossetti. 2010. "Multiple-Buyer Procurement Auctions Framework for Humanitarian Supply Chain Management". *International Journal of Physical Distribution & Logistics Management* 40(3):202–227.

Fikar, C., P. Hirsch, and P. C. Nolz. 2018. "Agent-Based Simulation Optimization for Dynamic Disaster Relief Distribution". *Central European Journal of Operations Research* 26(2):423–442.

Ghasemi, P., K. Khalili-Damghani, A. Hafezalkotob, and S. Raissi. 2019. "Stochastic Optimization Model for Distribution and Evacuation Planning (A Case Study of Tehran Earthquake)". *Socio-Economic Planning Sciences* 71:100–745.

Gore, R., P. Wozny, F. P. Dignum, F. L. Shults, C. Boshuijzen-Van Burken, and L. Royakkers. 2019. "A Value Sensitive ABM of the Refugee Crisis in the Netherlands". In *2019 Spring Simulation Conference (Springsim)*. April 29th -May 2nd, Tucson, Arizona, 1-12.

Green, J. L., O. L. De Weck, and P. Suarez. 2013. "Evaluating the Economic Sustainability of Sanitation Logistics in Senegal". *Journal of Humanitarian Logistics and Supply Chain Management* 3(1):7–21.

Guha-Sapir, D., P. Hoyois, and R. Below. 2015. "Annual Disaster Statistical Review 2014: The Numbers and Trends". Technical Report, Centre for Research on the Epidemiology of Disasters (CRED), Brussels, Belgium.

Hoyos, M. C., R. S. Morales, and R. Akhavan-Tabatabaei. 2015. "OR Models with Stochastic Components in Disaster Operations Management: A Literature Survey". *Computers & Industrial Engineering* 82:183–197.

Iakovou, E., D. Vlachos, C. Keramydas, and D. Partsch. 2014. "Dual Sourcing for Mitigating Humanitarian Supply Chain Disruptions". *Journal of Humanitarian Logistics and Supply Chain Management* 4(2):245–264.

Kitchenham, B. 2004. "Procedures for Performing Systematic Reviews". Technical Report, Department of Computer Science, Keele University, Staffordshire, UK.

Kunz, N., G. Reiner, and S. Gold. 2014. "Investing in Disaster Management Capabilities Versus Pre-Positioning Inventory: A New Approach to Disaster Preparedness". *International Journal of Production Economics* 157:261–272.

Leiras, A., I. De Brito Jr, E. Q. Peres, T. R. Bertazzo, and H. T. Y. Yoshizaki. 2014. "Literature Review of Humanitarian Logistics Research: Trends and Challenges". *Journal of Humanitarian Logistics and Supply Chain Management* 4(1):95–130.

Liu, Z., and T. Suzuki. 2018. "Using Agent Simulations to Evaluate The Effect of a Regional BCP on Disaster Response". *Journal of Disaster Research* 13(2):387–395.

Mishra, D., S. Kumar, and E. Hassini. 2019. "Current Trends in Disaster Management Simulation Modelling Research". *Annals of Operations Research* 283(1):1387–1411.

Mohan, S., M. Gopalakrishnan, and P. Mizzi. 2013. "Improving the Efficiency of a Non-Profit Supply Chain for the Food Insecure". *International Journal of Production Economics* 143(2):248–255.

Natarajarathinam, M., I. Capar, and A. Narayanan. 2009. "Managing Supply Chains in Times of Crisis: A Review of Literature and Insights". *International Journal of Physical Distribution & Logistics Management* 39(7):535–573.

Ochoa, A., I. Rudomin, G. Vargas Solar, J. A. Espinosa Oviedo, H. Pérez, and J. L. Zechinelli Martini. 2017. "Humanitarian Logistics and Cultural Diversity within Crowd Simulation". *Computacion y Sistemas* 21(1):7–21.

Octavia, T., C. Halim, I. G. A. Widyadana, and H. C. Palit. 2016. "Coordination of Humanitarian Logistic Model Plan for Natural Disaster in East Java, Indonesia". *International Journal of Supply Chain Management* 5(4):52–60.

Peng, M., H. Chen, and M. Zhou. 2014a. "Modelling and Simulating the Dynamic Environmental Factors in Post-Seismic Relief Operation". *Journal of Simulation* 8(2):164–178.

Peng, M., Y. Peng, and H. Chen. 2014b. "Post-Seismic Supply Chain Risk Management: A System Dynamics Disruption Analysis Approach for Inventory and Logistics Planning". *Computers & Operations Research* 42:14–24.

Seuring, S., and S. Gold. 2012. "Conducting Content-Analysis Based Literature Reviews in Supply Chain Management". *Supply Chain Management: An International Journal* 17(5):544–555.

Stauffer, J. M., A. J. Pedraza Martinez, L. L. Yan, and L. N. Van Wassenhove. 2018. "Asset Supply Networks in Humanitarian Operations: A Combined Empirical-Simulation Approach". *Journal of Operations Management* 63:44–58.

Suárez Moreno, J. D., C. Osorio Ramírez, and W. Adarme Jaimes. 2016. "Agent-Based Model for Material Convergence in Humanitarian Logistics". *Revista Facultad de Ingeniería Universidad de Antioquia* 81:24–34.

Swamy, R., J. E. Kang, R. Batta, and Y. Chung. 2017. "Hurricane Evacuation Planning Using Public Transportation". *Socio-Economic Planning Sciences* 59:43–55.

Thomé, A. M. T., L. F. Scavarda, and A. J. Scavarda. 2016. "Conducting Systematic Literature Review in Operations Management". *Production Planning & Control* 27(5):408–420.

Van Wassenhove, L. N. 2006. "Humanitarian Aid Logistics: Supply Chain Management in High Gear". *Journal of The Operational Research Society* 57(5):475–489.

Wang, Z., and J. Zhang. 2019. "Agent-Based Evaluation of Humanitarian Relief Goods Supply Capability". *International Journal of Disaster Risk Reduction* 36:101–105.

Widera, A., C. Konradt, C. Böhle, and B. Hellingrath. 2017. "A Multi-Method Simulation Environment for Humanitarian Supply Chains". In *The 4th International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*. December 11th-13th, Münster, Germany, 1-8.

Yorvarak, C., K. Takahashi, T. Sasaki, T. Kikuchi, and N. Harada. 2017. "Modelling of Logistic Network of Disaster Relief Using Similarity to Electric Circuit". In *International Conference On System Science And Engineering (ICSSE)*. July 21st-23rd, Ho Chi Minh, Vietnam, 739-742.

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