On the Literature Divergences of the Humanitarian Supply Chain

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Abstract. The field of humanitarian logistics has evolved rapidly over the past decade, drawing on contributions from the areas of operations research, business engineering, supply chain management, information systems, and computer sciences. Even more varied are the specific problems that are modeled and addressed, ranging monitoring of the supply chain as a whole to decision support for specific sourcing or distribution decisions. While recently, few studies have presented taxonomies and identified research gaps, there is to this date not yet a clear understanding of how the different methodologies and domains shall be combined to achieve a consistent mix of methods and tools. In this paper, we present a start towards this aim comparing two distinct perspectives and related research approaches, methods and tools: business engineering and operations research. Our findings indicate that there are real opportunities for interdisciplinary research to improve the overall performance of the humanitarian supply chain.

Keywords: Humanitarian supply chain · Operational research · Business engineering · Literature review

1 Introduction

There has been a remarkable raise on the numbers of humanitarian disasters during the last decade. Despite the increase of funding [1] still there is a significant gap between appeals and what is provided, hence the need for more effective and efficient response [2]. Humanitarian disaster management (HDM) is characterised by complexity, e.g., uncertainty, time pressure, or the large number of heterogeneous actors. Humanitarian supply chain (HSC) management plays a key role in disaster response and is recognized as a field of research [3]. Several literature reviews have been done to identify the gaps that research should address [4, 5], and different approaches applied to deal with the challenges raised [6, 7].

Although the performance of the response is contingent to meaningful knowledge integration across disciplines [8], research in the humanitarian field has often been

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limited to a disciplinary approach (e.g. operations research in humanitarian logistics). However, a multi- or interdisciplinary perspective can bring new insights, models and theories dedicated to the interplay of factors in real-world environments that are suitable for conceptual, analytical, empirical, and applied research [9].

The authors' backgrounds allowed us to review the HSC literature from two scientific angles: business-engineering science (BS) and operations research (OR). While BS aims at keeping track and aligning all processes in a supply chain, OR requires decomposing the supply chain into units that can be captured in abstract models [10]. We limited our study on four fundamental topics (HSC structure, flow control, time frames, and dynamic uncertainty) frequently addressed in literature. Our objective is to address the following research questions:

- What is the state of the art in HSC referring to those topics by focusing on BS and OR literature?
- What are future research directions in those topics according to BS and OR?

The novelty of this paper is this twofold focus on literature, which is illustrated by Fig. 1. This survey aims to contribute to the multi-disciplinary study of HSCs.

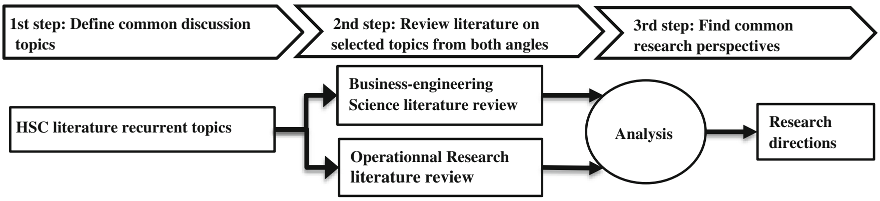

Fig. 1. Research Methodology

The rest of the paper is organized as follows: Sect. 2 discusses the research methodology; literature is reviewed in Sect. 3 by focusing on four specific topics; Sect. 4 provides the research needs; and the paper ends with conclusion at Sect. 5 by a summary of key findings.

2 Research Methodology

Following the well-known disaster management cycle, this review is dedicated to the response phase. Instead of conducting an exhaustive review, we conducted an exploratory study focusing on key publications in the areas of BS and OR. We start from identifying fundamental common topics to classify the literature in them.

BS focuses on a holistic view of the HSC. It looks at different flows and business processes that form the value chain: information, materials, financial, people (man power) and knowledge & skills [11]. OR pursuits to accomplish its contribution by focusing on detailed quantitative simulations and modeling [7]. While OR is more focused on logistics aspects, BS mainly focuses on relationships among the actors and organizational or management aspects.

To develop a classification we reviewed post-disaster HSC literature from both the BS and OR angle. In addition, we reviewed recent survey papers [4–7], to select a set of keywords to define our search chain, which was executed in GoogleScholar to ensure that a broad set of papers was covered. Our initial review revealed four joint areas of interest: HSC structure, flow control mechanisms, time frames, and dynamic uncertainty. The final selection was done on the basis of relevance of the articles to two scientific angles by reviewing their abstracts, findings and conclusions.

3 Literature Review

3.1 HSC Structure

According to the Council of Supply Chain Management Professionals, "*supply chain management integrates supply and demand management within and across companies*." HSC is not a series of discrete events in a linear process. According to a typical HSC shown by Fig. 2, it encompasses all activities involved in sourcing and procurement, conversion, and almost all logistics operations [12]. For more than a decade now, authors have tried to provide directions to advance HSC technology [13–15]. Following Hellingrath, Link and Widera [16], the main humanitarian-specific attributes are:

- Highly responsive (effective) instead of efficient (cost effective) processes,
- Uncertain and unpredictable demand,
- The role of donors as buyers and beneficiaries as end users,
- A highly volatile environment,
- Partly temporary and unknown supply chain design,
- Focus on procurement and distribution within the logistics value chain.

Mays, Racadio and Gugerty [15] insist that ignoring the differences can raise the risk of too focus on efficiency aims (e.g. operation cost) which may lead to less effective humanitarian efforts or divert from their stated mission and values. They suggest that academics should better contribute to HSC by a 'ground up' research design like the recent study of Chan and Comes [17].

However, HSC still suffers from key problems. In comparison to commercial supply chains (CSC), the process modeling of HSC is in its infancy [18]. The aim of process modeling is to help decision makers to optimize the processes by enabling a rapid visualization of HSC tasks. Although there are several successful approaches for CSCs, the applicability of existing solutions from the corporate world to the humanitarian sector is limited [19, 20].

Looking at the HSC mathematical models, previous surveys confirm that literature mainly focuses on a specific part of HSC [6, 7, 9]. Typically, simulations and modeling approaches are classified in three categories: facility location problems, distribution problems and inventory decision problems. Further investigation in each category reveals that also the focus on specific subproblems did not lead to much progress: Galindo and Batta [7] surveyed the existing literature of disaster operations management comparing to the similar work of Altay and Green [10] and didn't find any major change. Holguín-Veras, Jaller, Van Wassenhove, Pérez and Wachtendorf [9] highlight the urgency in

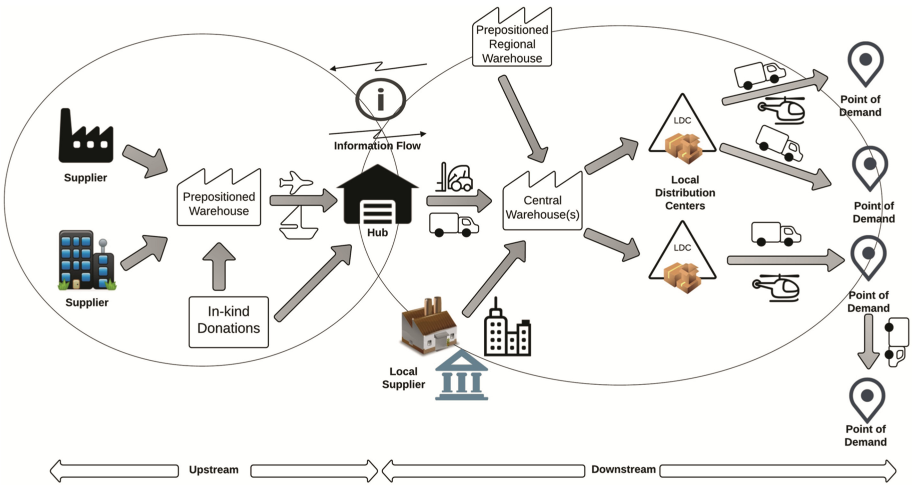

Fig. 2. A Typical HSC

understanding the specific HSC aspects like the decision making process. Similar literature review by Caunhye, Nie and Pokharel [21] depicted that research on transportation, like casualty transportation, is still limited. Luis, Dolinskaya and Smilowitz [22] pointed out that multi-period routing has not been modelled in the relief routing literature. Similar to Kunz and Reiner [23] findings, our review revealed that attention is dedicated mostly to the post-disaster, and specifically to distribution problems. There are a few common assumptions, which are frequently repeated in mathematical models. Realistic or not, these assumptions and constraints leave the field still interesting for further research. Several authors have also proposed solutions to solve humanitarian case-specific processes, or reference models transposable to several organizations [24].

Blecken [18] developed a reference model framework that is composed of two dimensions; hierarchical and structural. This framework can be used combined with the modeling language BPMN (bussiness process model and notation), as suggested by Blecken and then used by Franke, Widera, Charoy, Hellingrath and Ulmer [25] and Hellingrath, Link and Widera [16] among others. Furthermore, recent research suggest to take a step forward towards the use of simulation tools to evaluate modifications of the HSC network [16]. In the same way, Hofmann, Betke and Sackmann [26] propose a theoretical workflow management system to support a semi-automated analyses and adapting of ongoing disaster response processes.

3.2 Flow Control

The HSC networks, support essentially three different flows: Material, Information and Financial. The initial flow of material reflects the immediate reaction of actors according to the information transmitted [27]. It is necessary to provide accurate and timely information on what supplies are needed, what supplies was delivered to beneficiaries and where [28]. However, most NGOs manage the response processes mainly based on experience, and the concept of flow control, or performance, is poorly understood [29].

Improved information flow is also necessary for performance management [4]. There are only few publications on performance measurement systems (PMSs). Key performance indicators (KPIs) are a way to 'control the flow' of HSC [29, 30], yet this field is still in its early steps. A recent review by Abidi, de Leeuw and Klumpp [4] indicates that while there are some theoretical considerations, the number of contributions that deal with real situations in HSCs is low. In addition, there is no convergence on which performance indicator or evaluation framework is suitable for specific situations.

Information systems have been developed to support HSC management. Blecken and Hellingrath [31] did a comparative analysis concluding that currently, no software system responds to all requirements of HSC: Planning; Documentation; Reporting; Cross-linking of systems; Offline use & Synchronization; Modularity & Adaptability; Tracking & Tracing; User friendliness, Training; Software costs and Hardware costs. They suggest to use commercial solutions that are better developed e.g. OpenERP (UniField) by MSF [32].

Another approach is Value Stream Analysis. Taylor and Pettit [33] did a theoretical study of the use of such a Lean Management approach and raised some challenges for the use of this "commercial" approach: 1) the transitory nature of HSCs; 2) HSCs should operate effectively from the start; 3) there is a need to improve the performance in real time as well as after the response.

In comparison to BS which mainly looks for monitoring indicators to establish flow control, OR primarily focus on network flow models with the objective of optimizing the flow of supplies through these networks. It discusses different modes of flow in distribution plan problems in time dependent approaches and models the commodity flow in distinct distribution network styles, for instance dynamic network [34] and static network [35], or sometimes in resource allocation [9].

In mathematical models, typically, relief goods, equipment, and personnel "flow" in almost zero lead-time from the source to the beneficiary using ad-hoc distribution facilities and networks [36]. This approach might work if suppliers comply to provision of specific items or services in a prearranged time frame. It is also unrealistic to develop models based on reliable commodity flow. Sometimes, assumptions are also affected by political instability, infrastructure, topography, and the limited (or non-existent) transportation capacity in the affected area [37].

Furthermore, material convergence—the spontaneous flow of supplies, donations, and equipment to a disaster area— is a poorly understood phenomenon and comprises three groups [38]: 1. High-priority supplies for immediate distribution and consumption, 2. Low-priority supplies that are not immediately needed but could be useful later, and 3. Non-priority supplies that are not of any use. To prevent losses (or diversions) and convergences, and ensure a more efficient use of resources, one idea could be to track the supplies and establish controls to indicate what types of supplies have been mobilized, in what quantity, and condition. They could also identify the parties that have intervened in the process.

3.3 Time Frames

A large amount of literature HSC management focuses on the response phase of a disaster [39]. This could be influenced by: (1) the significant role of logistics in this phase; (2) the key objective of saving lives during response phase; and (3) the huge amount of media coverage in comparison to other phases.

The response phase covers all actions to be carried out after an initiating hazard event. Regardless of crisis nature, humanitarian operations can be classified in distinct time frames: ramp-up, mature/sustain, and ramp-down [40]. Ramp-up is equivalent to the "immediate-response" which is defined by Cozzolino [41]. During this stage, supplies are pushed to the disaster location [12], and there is a priority on effectiveness. The transition to the sustain and ramp-down phases involves a shift in HSC management focus from speed to cost reduction in terms of operational performance [40], or from agile to lean principles.

The paradigm between leanness and agility has been discussed a few times (i.e. by Cozzolino [41] and Heckmann, Comes and Nickel [42]). However, this transition can be also seen in the HSC stream relating to the choice of *decoupling points*. We found some literature concerning the hybrid *leagile* HSC, suggesting the combination of lean and agile approaches [43]. First impressions are pointing to support IT developments for adopting such strategies.

The changing environment is an important challenge requiring a flexible HSC. To deal with the issue of flexibility, there are several research addressing problems in single time periods [44], a few contributions have struggled with multi period modelling [39], neglecting the fact that the deployed network is usually temporary and needs to be flexible to accommodate the demand's variation in different time frames. Moreover, in a multi-period planning horizon, site's costs and capacities may impact the decisions, turning the selection of appropriate time step in multi period modelling into a significant factor that can dramatically affect the performance of time-space networks [34]. In short: to keep the problem manageable, it is favourable to have longer time steps but shorter time steps will improve the accuracy of modelling the emergency response operations. Beyond these response related issues, Kunz and Reiner [23] concluded that more attention needs to be paid to the logistics operations with longer-term considerations, spanning into the development phase.

Considering the OR's literature on multi period modeling, specifically in distribution plans, nearly 50 % of contributions on logistics networks aim to minimize cost. In the transportation problems the objectives focus more on the speed or the satisfaction of demand. All of the abovemention as well as social costs and priority are recognized as key objectives in OR literature, and monodimensional problems are considered as limited and unrealistic [6]. To be as close as possible to reality, distributions plans (or models) not only should work in multi periods, their objective function should include a combination of objectives at the same time to reflect the complexity of decision making.

3.4 Dynamic Uncertainty

HSC involves a large numbers of actors and stakeholders (beneficiaries, host governments, local and international relief organizations, donors, etc.) and operates in highly unpredictable, dynamic environments. Hence, disaster response activities vary widely and are driven by numerous factors depending on each situation. Lack of efficiency and misalignment of the response with the real situation are common implications of uncertainty. These difficulties are linked to considerations of time frame (and pressure to make decisions) and flow control (information), the integration of uncertainty is a separate step.

From the BS point of view, uncertainty has makes long-term planning difficult and prevents supply chains from reaching a stable equilibrium. This suggests a few research challenges: (1) short term forecast and prediction of patterns could be made; (2) the chaos can be reduced if the focus is on the beneficiaries' needs and (3) the simulation of the HSC system and dynamics analysis of key parameters can help to prevent chaos (inspired on Wilding [45]).

Upon severe uncertainty, the order quantity determines the quantity delivered by a supplier which is a random variable. Quite contrary in capacity uncertainty, the delivery capacity is a random variable that is typically independent of the order quantity. Lead-time uncertainty is a stochastic element in the order lead time and input cost uncertainty represents stochasticity in the procurement prices [46]. To face these uncertainties appropriately, decision support systems could be developed to enable decision makers to have a clear vision of the on-going situation (real-time) as well as future of demand (predictive management).

Dynamic uncertainty in the aftermath of disasters may result in the need to move or relocate facilities such as shelter, warehouse and distribution centres. HSC may face an updated dynamic problem according to the new scenarios of catastrophe. Trends in using static data modelling reveals that stochastic and dynamic models are harder to solve. However, stochastic and scenario-based data modelling can help the decision makers to represent the uncertainty related to the process of the impact's estimation; closer to the chaotic circumstances of disasters.

Significant effort is still needed to efficiently solve these kinds of models; appropriate solutions must generate good relief plans in a short time. Therefore, we suggest an integrated perspective that includes the analysis of the interrelation between decision levels [6]. Literature shows that many contributions have been made on one stage or the other, but the integrated approaches are still rare.

4 Research Directions

HSC management still has many open issues and is therefore relevant for mathematical modeling, actual applications, and multidisciplinary perspectives to get a holistic analysis in the decision-making process [47]. Looking at the literature of HSC from different angles, BS and OR, we found that there are common topics: structure, flow control, time frame and dynamic uncertainty. In the following paragraphs, as summerized by Fig. 3, we will highlight research directions for each of these dimension.

HSC Structure. Literature shows the demand for grounded research design for better understanding the real challenges practitioners face. It is not sufficient to bring limited CSC solutions to the HSC as long as they do not fulfil the user requirements. Reviewed papers in OR indicate that research focuses on specific parts of HSC like distribution

Topics	Business-engineering Science	Operational Research
Structure	- Need of ground up research design - Applicability of existing CSC solutions to the HSC is limited - Simulation tools to help decision makers to evaluate network changes	- Reviewed papers are mainly focused on a specific part HSC - Distribution plans in decision making process are important - Unrealistic assumptions and constraints for optimization models and also insufficient objectives
Flow control	- Insufficient information for decision making - Importance of change management to use PMS (still in early stage at the field) - Need of Performance indicator for specific situations - VSA (lean) approach (challanges /oportunities) to optimise processes	- To find a way to consider facility ability in OR - The problem of material convergence at primary hubs and bottlenecks
Time frames	- Need of a DSS to combine the concepts of agility and lean to find a hybrid leagile management system that suits each time-frame.	- Multy-periods modelling to deal with changing environment - Multy-objectives modelling at same time - Modelling evolving to short time frames
Dynamic uncertainty	- Need of a clear vision of the HSC (real-time) - Use of predictive management to face dynamic uncertainity	- Refflecting uncertainity by stochastic/dynamic modelling - Need of efficient solving methods - Testing different scenarios to anticipate

Research Directions

-Development of "practitioners-friendly" PMS (real-time), which include the identification of supplies status (OR) through various stages of HSC (BS).

- Converge on the definition of time frames to facilitate vertical integration of BS and OR approaches.

- Development of stochastic (predictive) approaches to support decision makers in uncertainty.

- Development of a DSS to support leagile strategy to deal with efficiency vs. effectiveness paradigm.

Fig. 3. Synthesis of the litterature review

plans. However, to develop more realistic models, OR researchers have to avoid unrealistic assumptions and constraints. In this context, BS also suggests more use of simulation tools to evaluate modifications of HSC network.

Flow Control. BS literature suggests that there is insufficient information to assist decision makers. The common approach of developing PMSs is immature and change management has an important impact on PMS establishment. By concentrating on specific situations, literature lacks convergence on specific performance indicators. The newly introduced approach of VSA is still struggling with challenges in controlling processes. While field experts are suffering from material convergence at primary hubs and bottlenecks, OR has not yet found a way to reflect these challenges in mathematical models. Hence, developing a PMS which can also identify the status of supplies through various stages of HSC can be a step forward for both BS and OR.

Time Frames. Due to the importance of response phase and the transition from rapidity to cost optimisation in HSC during response time frames, BS suggests to find a hybrid *leagile* management system. OR follows its recent trend toward developing models on the basis of shorter time frames to better reflect dynamics. To show the temporal network, these multi period models need to be flexible enough to capture variations during response. Furthermore, literature asks for multi-objective contributions to reflect the complexity of decision making.

Dynamic Uncertainty. The relief organisations have tried to develop agile HSCs, but practitioners still deal with significant misalignments. BS insists on improving real time assessment as well as developing predictive DSS to reduce this unbalancing. From the other angle, when OR concentrates to address dynamic uncertainty, it refers to the merits (or demerits) of stochastic/dynamic models in comparison to deterministic ones.

Since there is not much efficient solving methods for these kinds of models, OR asks for further research in this area; which will ease the way through developing integrated models to reflect real situations better.

5 Conclusion

Our investigation reveals that both BS and OR have common interests in HSC. Both of them are trying to develop a PMS (in their own research area) and they need more improvement in related simulation systems. While OR is searching for an optimised time scale for its dynamic models, BS is also looking for a time-period to use its indicators on real-time basis. Furthermore, both BS discussion about predictive management and OR attempt in reflecting uncertainty in models by including probability (stochastic modelling), can contribute in developing an integrated stochastic approach. This approach can lead to a decision support system which considers different scenarios to assist in facing dynamic uncertainty.

This research tried to address the state of the art in four common frequently repeated topics of both sciences in HSC. However, there are other areas which can be added to our list for future like collaborative networks and virtual organizations. Literature review depicts some research directions, shown by Fig. 3, which ask for further study. As the outcome, authors are currently working on these directions and believe that cooperation between their research areas in the mentioned topics can result in more efficient and effective HSC.

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