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Executive Summary of the Thesis

Humanitarian Supply Chains: an analysis of SC responses to natural disasters and large disruption events

Laurea Magistrale in Management Engineering - Ingegneria Gestionale

Author: Mattia Longobardo , Matteo Schiattarella

Advisor: Prof. Andrea Sianesi

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1. Introduction

The contemporary global context is defined by an escalating and deeply concerning proliferation of crises. From "people fleeing violence, houses destroyed by bombs, storms, fires, earthquakes", the evidence points to a structural shift in global instability. This thesis begins by quantifying this trend, noting that over the last fifty years, the number of annually recorded natural disasters has surged from an average of 70-80 in the 1970s to consistently over 400 today. This dramatic rise is primarily driven by climate change, which intensifies the frequency and destructive power of extreme weather events, ruining crops, fueling social tensions, and rendering entire regions of the planet uninhabitable. In parallel, the landscape of armed violence has become more complex and lethal. The number of active conflicts worldwide more than doubled from 86 in 2010 to 180 in 2024, with the number of directly involved countries growing from 37 to 59 in the same period. The human toll is staggering, with conflict-related deaths rising from approximately 50,500 in 2010 to a peak of over 311,000 in 2023. This reflects not only the quantity of conflicts but also their increased "intensity and brutality".

A direct and catastrophic consequence of this escalating instability is the unprecedented growth in the number of internally displaced persons (IDPs). Defined by the Internal Displacement Monitoring Centre (IDMC) as individuals "forced or obliged to flee... their homes... and who have not crossed an internationally recognized State border", this population nearly doubled in less than a decade, soaring from 40.5 million in 2015 to 75.9 million by the end of 2023. This figure reflects both prolonged conflict-driven displacement—often long-term as people cannot return until peace is restored—and intense, often time-limited displacement from sudden-onset disasters.

This humanitarian reality places immense and unsustainable pressure on Humanitarian Supply Chains (HSCs). An HSC is defined as "the process of planning, implementing, and controlling the efficient and cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption, in order to alleviate the suffering of vulnerable people". Historically, HSC management has been predominantly based on the direct, often tacit, experience of field operators. However, in the face of growing complexity, stakeholder diversity, and resource scarcity, this reactive and experience-based approach is prov-

ing insufficient. A paradigm shift has become urgently necessary: moving from an experience-based decision-making model to a **data-driven** one, founded on quantitative analysis and strategic foresight,

2. Objectives

This thesis originated from an initial inquiry into optimizing logistics flows but pivoted upon discovering that many humanitarian organizations lack the granular, standardized data required for such models. This realization reshaped the research to address more fundamental questions. The primary objective thus became the **identification, validation, and ranking of the Critical Success Factors (CSFs)[1]** that determine the effectiveness of logistical responses in emergency contexts. The goal is to provide a clear, actionable framework that can guide strategic decisions even in data-scarce environments.

The specific objectives of this work are designed to provide tangible value to the humanitarian sector:

- **To provide an evidence-based strategic roadmap** for humanitarian organizations. In a resource-scarce environment, this roadmap helps prioritize investments and strategic initiatives, moving beyond anecdotal evidence to focus on areas with the highest proven impact on operational success.
- **To develop an innovative conceptual model** for interpreting the complex dynamics of humanitarian operations. The proposed "Demand/Supply" framework helps to untangle the intricate interplay of variables, offering a clearer analytical lens to distinguish between external pressures and internal capabilities.
- **To propose and demonstrate the utility of advanced quantitative tools** to support decision-making. By employing methods like the Analytic Hierarchy Process (AHP)[5] and simulation modeling, this work introduces a level of rigor and objectivity to a field that has traditionally relied on intuition, enabling more robust planning and risk assessment.
- **To promote a cultural change** within the humanitarian sector. This involves advocating for a shift away from over-reliance on individual experience—a significant vulnerability in a field with high staff turnover—towards building resilient institutional knowledge that is systematic, analytical, and data-driven.

3. Research Methodology

To achieve these objectives, a rigorous, multi-phase research methodology was adopted, synergistically combining qualitative and quantitative approaches to ensure both depth and reliability.

1. **Qualitative Phase – Structured Interviews:** The research began with structured interviews with professionals from nine of the world's leading humanitarian organizations, including WFP, ICRC, MSF, and Direct Relief. The initial pool of over forty organizations was narrowed to ensure intentional diversity in size and specialty. This phase was crucial for gathering tacit knowledge and understanding real-world operational challenges, exploring key areas such as preparedness protocols, supplier relationships, risk assessment, and performance metrics. All interviews were conducted with strict adherence to ethical guidelines, including informed consent and caution regarding politically sensitive information.
2. **Crisis Classification – Analytic Hierarchy Process:** To objectively select the most relevant case studies, the AHP was employed. This method structures complex, multi-criteria problems by using pairwise comparisons on a 1-9 scale to quantify subjective expert judgments. Two distinct rankings—one for natural disasters and one for armed conflicts—were created based on weighted variables . The resulting data was normalized and categorized using the MOSCOW model . The process demonstrated high robustness, achieving a Consistency Ratio of 0.066 for the disaster matrix and 0.0795 for the conflict matrix, both well below the 0.1 threshold of acceptability. An example of the formula used is:

$$\begin{aligned}\text{Score} = \mu_1 \times \text{Fat} + \mu_2 \times \text{Area} \\ + \mu_3 \times \text{News} + \mu_4 \times \text{Cost} \\ - \mu_5 \times \text{LPI}\end{aligned}$$

where *Fat* represents Fatalities, *News* the

number of newspaper articles, and *Cost* the total damage cost.
This structured process enabled the selection of five emblematic case studies for in-depth analysis: Nepal Earthquake (2015), Pakistan Floods (2022), Russo-Ukrainian War (2022), Democratic Republic of Congo Conflict (2012), and United States Hurricane (2017).

3. **Factor Ranking – Delphi Method:** The critical factors identified from the literature and interviews were validated and ranked using a two-round Delphi methodology[4], a structured group communication process originally developed by the RAND Corporation. This method was chosen to mitigate the drawbacks of face-to-face discussions, such as groupthink, by using structured anonymity. The same panel of NGO experts was engaged in an iterative process. In Round 1, they scored each factor's importance and provided comments. In Round 2, they received an anonymized summary of the group's average scores and thematic feedback, allowing them to reflectively revise their initial assessments. This led to a strong, refined consensus, with the average absolute delta between scores decreasing from 1.02 to 0.37, indicating significant convergence.

4. Main Research Findings

The analysis conducted yielded significant and actionable results that form the core of this thesis, moving from broad theoretical adaptations to specific, empirically validated priorities.

4.1. Adapting Commercial Logic: The Triple-A Framework in HSCs

A foundational finding is that while commercial supply chain models (like SCOR) are not directly transferable to the humanitarian context, their core principles can be adapted. The thesis explores Lee's "Triple-A Supply Chain"[3] framework, re-contextualizing its pillars for HSCs:

- **Agility:** The ability to respond rapidly to sudden spikes in demand, such as diverting pre-positioned goods after an earthquake. This is a core requirement in all sudden-onset disasters.
- **Adaptability:** The long-term evolution of the supply chain, such as establishing permanent regional warehouses in disaster-prone areas or training local staff to build sustainable capacity.
- **Alignment:** The harmonization of objectives among diverse stakeholders (NGOs, donors, governments), which is arguably the most challenging aspect due to differing mandates and the lack of a unifying profit motive.

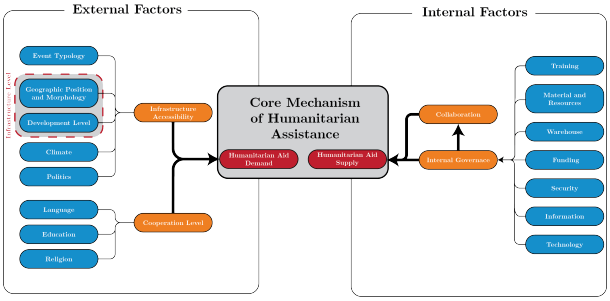

Figure 1: Causal Model of Humanitarian Assistance Dynamics

4.2. Causal Model of Humanitarian Aid Dynamics

Building on this, a conceptual model was developed (fig. 1) that distinguishes between **"Humanitarian Aid Demand"** and **"Humanitarian Aid Supply."**

- **Humanitarian Aid Demand** is shaped by *external factors*. These include "Infrastructure Accessibility" (influenced by a country's geography, politics, and development level) and "Cooperation Level" (influenced by local language, education, religion). For example, the mountainous terrain of Nepal (*External Factor*) dramatically complicated infrastructure accessibility and shaped the demand for specialized logistical solutions like using pack animals.
- **Humanitarian Aid Supply** is determined by *internal factors* within an organization's control. Key variables such as Training, Funding, and Resource Management feed into an organization's "Internal Governance" and "Collaboration" capabilities, which in turn define its capacity to deliver assistance effectively.

4.3. An Empirically-Grounded Hierarchy of Critical Success Factors

The central result of the research is the clear hierarchy of success factors that emerged from the Delphi method (fig. 2), providing an empirical ranking of strategic priorities. Three factors were identified as being in a tier of their own, indicating they are foundational to success.

1. **Management of Materials and Resources (Average Score: 8.2):** This was ranked as the single most critical factor. It encompasses strategic procurement, quality control of goods, and robust inventory management, including the pre-positioning of buffer stocks. The Pakistan floods case study powerfully illustrated this, where the pre-existing Humanitarian Response Facilities (HRF) network was a key asset, but challenges in last-mile delivery due to damaged infrastructure highlighted the importance of a resilient resource pipeline.
2. **Quality and Transparency of Information (Average Score: 8.1):** The ability to collect, share, and utilize reliable real-time data is deemed essential for coordination and effective decision-making. Experts consistently highlighted that data silos between agencies and a reluctance to share information undermine the entire humanitarian ecosystem. The response in Ukraine demonstrated the value of the Logistics Cluster's role as an information hub, using tools like Situation Reports (SitReps) to synchronize operations among dozens of partners.
3. **Warehouse Efficiency (Average Score: 8.0):** This encompasses strategic positioning, the rigorous adoption of inventory policies (e.g., FEFO/FIFO), and the logistical capacity to rapidly deploy resources. The Ukraine crisis highlighted the success of a forward positioning strategy, with hubs established in Poland and Romania to feed aid into the country. Similarly, the use of Mobile Storage Units (MSUs) in Nepal provided the flexibility needed in a dynamic post-earthquake environment.

Factors such as *Development Level*, *Training*, *Funding*, and *Technology* were ranked in a second tier (scores between 7 and 8), acting as critical "amplifiers". The varying priorities among

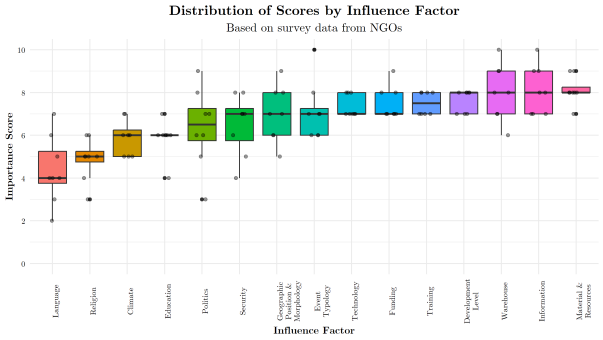

Figure 2: Distribution of Influence Factor Scores

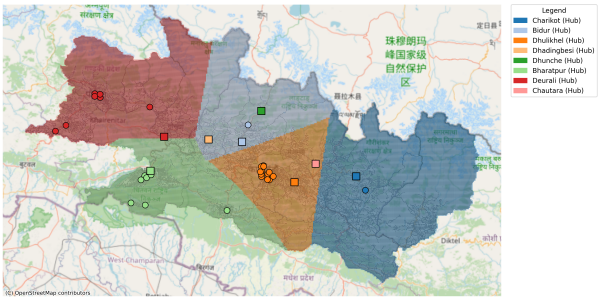

Figure 3: Map of the Best MSU Locations as Determined by the Genetic Algorithm

different NGOs were also evident, with logistics-focused agencies like WFP rating technical factors higher than medical-focused organizations like Emergency.

4.4. A Proof of Concept for Data-Driven Warehouse Optimization

As a practical application, a *Proof of Concept* simulation model was developed to optimize the placement of 30 mobile storage units (MSUs) in the Nepal earthquake case study. The model's objective was to minimize the maximum service time to beneficiaries while respecting vehicle and capacity constraints. Two advanced optimization approaches were compared: a **Genetic Algorithm (GA)** and a **Reinforcement Learning (PPO)** model. While the GA produced a marginally better result (max service time of 6.56 hours vs. 6.84 hours) and was computationally faster for this fixed scenario, the PPO model offers greater potential for generalization and online re-optimization. This PoC demonstrates that such tools can provide robust, data-driven solutions and enable powerful "what-if" scenario analysis, moving planning beyond intuition.

5. Conclusions

This thesis has traced a path from observing a growing global humanitarian need to identifying and prioritizing the critical factors that enable success in HSCs. The research confirms that while external contexts are challenging, humanitarian organizations can drastically improve their effectiveness by acting on a set of well-defined internal levers.

Contributions to Knowledge This research contributes to the field by:

- **Confirming** the validity of established frameworks, , such as the disaster management phases (preparedness, response, and recovery) detailed by Kovács and Spens [2], and the applicability of the Triple-A Supply Chain principles to the humanitarian sector.
- **Adding** new, practical knowledge through the empirical ranking of CSFs, which elevates Materials, Information, and Warehouses as the foundational triad for investment. The "Demand/Supply" model also offers an innovative framework for analysis.
- **Revising** the scope of existing theories, demonstrating that direct import of commercial SC models is inadequate without profound adaptations , and suggesting that certain cultural barriers are now perceived as more manageable than core logistical challenges.

Limitations of the Study The study's conclusions should be considered in light of its limitations, including a small (though expert) sample of NGOs, a limited number of case study typologies, simplifications in the optimization model, and challenges in accessing disaggregated quantitative data.

Final Conclusions The primary implication of this research is a clear call to action.

1. **Targeted Investments:** The evidence strongly suggests that humanitarian organizations should concentrate their strategic investments on the foundational triad of factors: **materials management, information systems, and warehouse optimization**. These form the bedrock of an effective logistical response.
2. **Adoption of a Data-Driven Approach:** It is imperative to accelerate the transition from experience-based management to a culture guided by data. The adoption of technologies for simulation, optimization, and predictive analytics is no longer an option but a necessity to manage complexity.
3. **Bridging the Training Gap:** There is a critical need for structured, advanced training in humanitarian logistics. This thesis proposes the creation of an **integrated educational platform between universities and NGOs** to standardize essential skills, foster innovation, and build a resilient talent pipeline in a sector marked by high staff turnover.

In a world where crises are increasingly interconnected, efficiency, resilience, and collaboration are not just goals, but a "moral imperative". Investing in these capabilities is the primary path to ensure that humanitarian aid is delivered in the fastest, most effective, and most humane way possible, maximizing the number of lives saved

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