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# Humanitarian Supply Chains: an analysis of SC responses to natu- ral disasters and large disruption events

TESI DI LAUREA MAGISTRALE IN  
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Author: **Mattia Longobardo** , **Matteo Schiattarella**

Student ID: 232666, 245218  
Advisor: Prof. Andrea Sianesi  
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# Abstract

In today's global context, characterized by an escalation of natural disasters, armed conflicts, and large-scale disruptive events, **Humanitarian Supply Chains** are under unprecedented pressure. The exponential increase in the number of internally displaced persons and the growing complexity of operational scenarios demand a logistical response that is increasingly efficient, agile, and resilient. This thesis aims to identify and prioritize the critical success factors that determine the effectiveness of logistical responses in such scenarios, with the goal of providing a strategic framework for the improvement of humanitarian operations. The research began with a qualitative phase, based on structured interviews with professionals from nine of the world's leading NGOs. Subsequently, the Analytic Hierarchy Process was applied to objectively classify recent humanitarian crises and select five emblematic case studies, which were analyzed in-depth. Finally, through a two-round Delphi methodology with the same experts, the identified critical factors were validated and empirically ranked to establish their relative importance. The main findings reveal a clear hierarchy of success factors. The management of **Materials and Resources**, the quality and transparency of **Information**, and the efficiency of **Warehouses** emerged as the three highest-impact elements, surpassing other variables traditionally considered central. The study also developed a conceptual model that distinguishes between "Humanitarian Aid Demand," influenced by external factors, and "Humanitarian Aid Supply," determined by internal factors within NGOs. As a practical application, a *Proof of Concept* simulation model was developed for warehouse placement optimization. This research provides humanitarian organizations with an evidence-based strategic roadmap to enhance their operational effectiveness, suggesting investments on the highest-priority factors. The work promotes a paradigm shift from a decision-making approach based predominantly on experience to one that is data-driven, with the ultimate objective of making the humanitarian response more agile, resilient, and efficient, thereby maximizing the number of lives saved.

**Keywords:** Humanitarian Supply Chain (HSC), Humanitarian Logistics, Emergency Management, Critical Success Factors, Delphi Method, Supply Chain Optimization, Analytic Hierarchy Process (AHP), Machine Learning.



## Abstract in lingua italiana

Nel contesto globale odierno, caratterizzato da un'escalation di disastri naturali, conflitti armati ed eventi dirompenti su larga scala, le **Humanitarian Supply Chain** sono sottoposte a una pressione senza precedenti. L'aumento esponenziale del numero di sfollati interni e la crescente complessità degli scenari operativi richiedono una risposta logistica sempre più efficiente, agile e resiliente. Questa tesi si propone di identificare e dare priorità ai fattori critici di successo che determinano l'efficacia delle risposte logistiche in tali scenari, con l'obiettivo di fornire un quadro strategico per il miglioramento delle operazioni. La ricerca è iniziata con una fase qualitativa, basata su interviste strutturate a professionisti di nove ONG leader a livello mondiale. Successivamente, è stato applicato il Analytic Hierarchy Process per classificare oggettivamente le recenti crisi umanitarie e selezionare cinque casi di studio emblematici, che sono stati analizzati in profondità. Infine, attraverso una metodologia Delphi a due round con gli stessi esperti, i fattori critici identificati sono stati validati e classificati empiricamente per stabilirne l'importanza relativa. I risultati principali rivelano una chiara gerarchia dei fattori di successo. La gestione di **Materiali e Risorse**, la qualità e la trasparenza delle **Informazioni** e l'efficienza dei **Magazzini** sono emersi come i tre elementi a più alto impatto, superando altre variabili tradizionalmente considerate centrali. Lo studio ha anche sviluppato un modello concettuale che distingue tra "Domanda di Aiuto Umanitario", influenzata da fattori esterni, e "Offerta di Aiuto Umanitario", determinata da fattori interni alle ONG. Come applicazione pratica, è stato sviluppato un modello di simulazione *Proof of Concept* per l'ottimizzazione del posizionamento dei magazzini. Questa ricerca fornisce alle organizzazioni umanitarie una roadmap strategica basata sull'evidenza per migliorare la loro efficacia operativa, suggerendo investimenti sui fattori a più alta priorità. Il lavoro promuove un cambio di paradigma da un approccio decisionale basato prevalentemente sull'esperienza a uno guidato dai dati, con l'obiettivo finale di rendere la risposta umanitaria più agile, resiliente ed efficiente, massimizzando il numero di vite salvate.

**Keywords:** Catena dell'Approvvigionamento Umanitario, Logistica Umanitaria, Gestione delle Emergenze, Fattori Critici di Successo, Metodo Delphi, Ottimizzazione della Catena dell'Approvvigionamento, Analytic Hierarchy Process (AHP), Machine Learning.



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# 1 | Introduction

## 1.1. Humanitarian Supply Chain

People fleeing violence, houses destroyed by bombs, storms, fires, earthquakes, improvised camps filled with families that have lost everything. The images coming from Gaza, Ukraine, and Gazantiep represent only the most recent evidence of a global trend of increasing destruction and civilian displacement.



Figure 1.1: A Palestinian man returns to Jabalia refugee camp on 30 May 2024, after Israel began its withdrawal from the area (AFP/Omar Al-Qattaa) Middle East Eye [26]

Over the last fifty years, there has been a dramatic increase in both extreme climatic events and armed conflicts. If, in the 1970s, there were about 70–80 natural disasters annually, that figure now consistently exceeds 400, indicating a staggering rise. This trend is driven primarily by increasing global temperatures, which intensify extreme weather events, making them more frequent, unpredictable, and destructive. Among the most

devastating events are floods, which numbered around 20–30 per year in the 1960s but have soared in recent decades, reaching 222 cases in 2021, with peaks such as the 232 recorded in 2006. A similar pattern is seen in extreme temperatures, which were almost negligible until the 1980s but grew progressively to 52 incidents in 2012 and 40 in 2022. Thus, Climate change amplifies phenomena once considered rare, turning them into concrete, recurring threats. One example is drought, which in the 1960s stood at around ten occurrences per year, whereas it now strikes at four times that frequency, with 40 occurrences in 2022 alone. The consequences are arid land, ruined crops, food insecurity, and water crises affecting millions of people, fueling social tensions and forced migration flows. This growth in extreme events is not merely a statistical curiosity but a structural shift redefining how communities live and survive. Entire regions of the planet are becoming uninhabitable, with populations compelled to abandon their homes due to increasingly devastating floods, unbearable heatwaves, and barren lands incapable of supporting agriculture or livestock. In this context, climate change is no longer a distant threat but a tangible reality striking with growing intensity, exacerbating existing inequalities, and driving global instability.

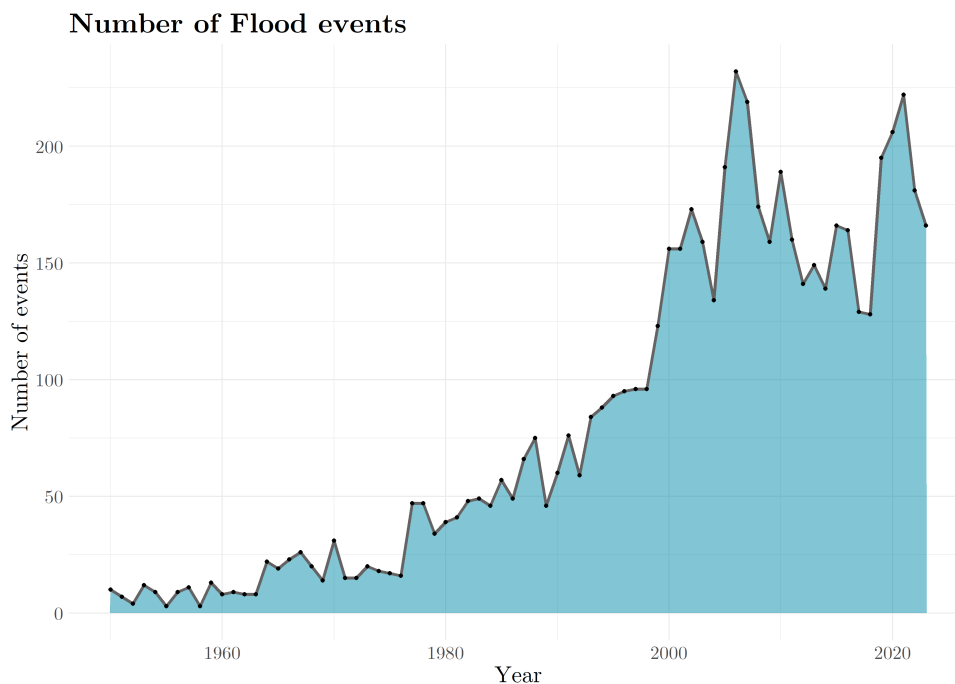


Figure 1.2: Flood Events since 1950 Our World in Data [29]

In addition to natural disasters, armed conflicts have also become more widespread, protracted, and lethal, significantly contributing to global instability. Over the last 15 years, about 2 million people have lost their lives due to wars, guerrilla activities, and armed violence—an alarming figure that highlights how scenarios of instability and suffering

increasingly mark the world. The number of conflicts is constantly increasing: if there were 86 worldwide in 2010, by 2024, that figure had more than doubled, reaching 180. In parallel, the number of countries directly involved in wars or internal conflicts has grown from 37 in 2010 to 59 in 2024.

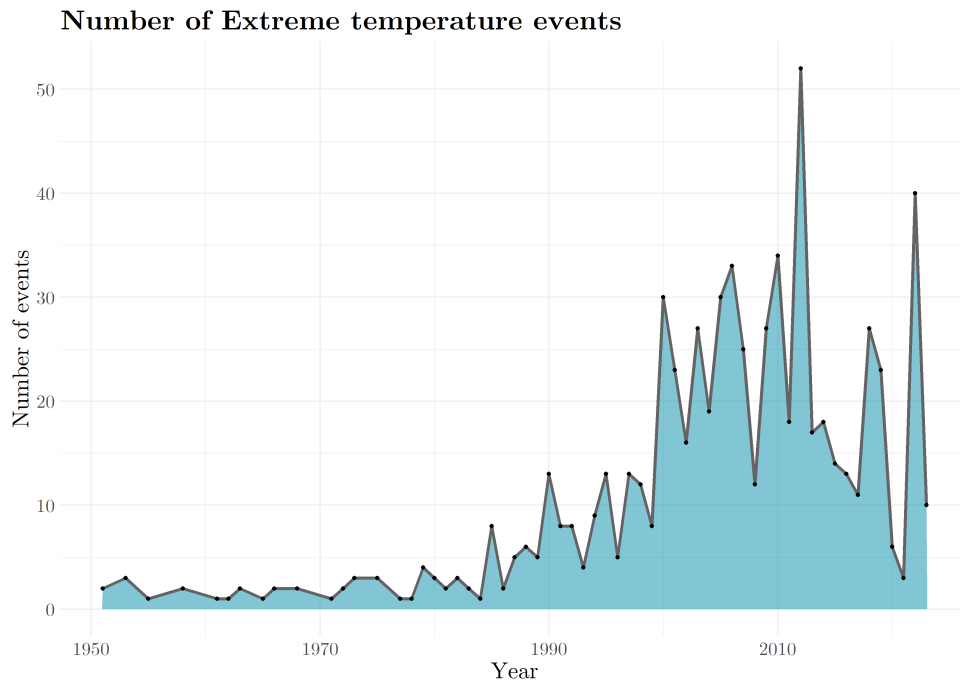


Figure 1.3: Extreme Temperature Events since 1950 Our World in Data [29]

The human toll of this escalation is devastating. In 2010, the number of deaths caused by conflicts was around 50,500, whereas in 2023, it reached a dramatic peak of over 311,000 in a single year. This increase not only reflects the growing number of conflicts but also their intensity and brutality, often exacerbated by the indiscriminate use of increasingly destructive weapons and the brutalization of warfare. Regions that were once relatively stable have become epicenters of violence. At the same time, conflicts that seemed on the verge of resolution have turned into chronic wars, dragging entire generations into a spiral of devastation. The direct and catastrophic effects on civilian populations are profound: they bear the highest price in terms of loss of life, destruction, and forced displacement. The number of refugees and internally displaced persons has risen sharply: millions have been forced to leave their homes to escape bombings, massacres, and persecution.

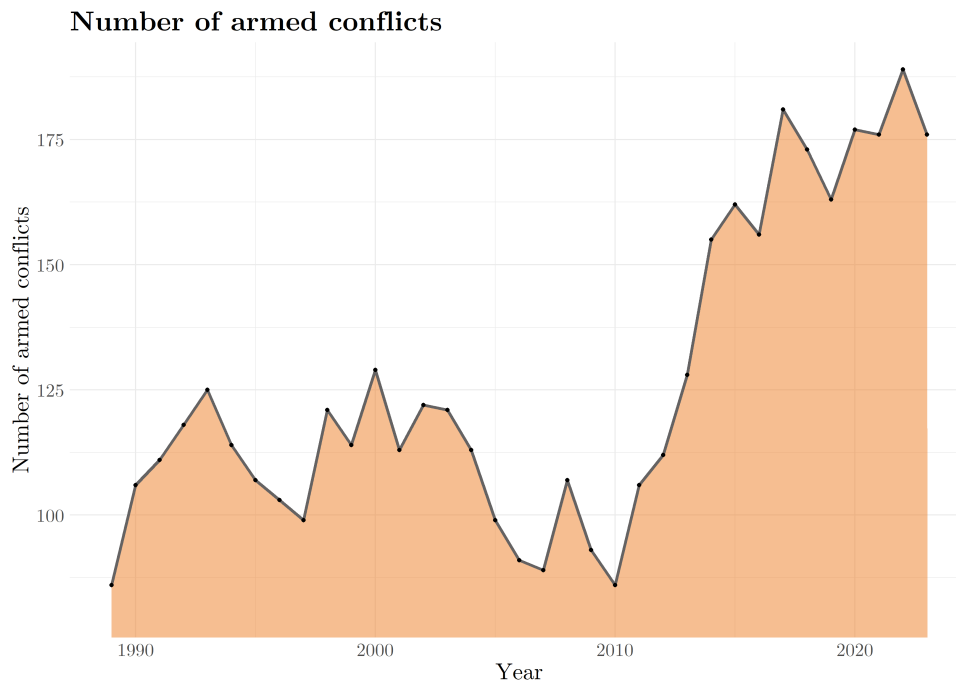


Figure 1.4: Armed Conflicts since 1990 Our World in Data [30]

Images from Gaza, Ukraine, and Gazantiep are just the latest in a long sequence illustrating the growing upheaval and displacement of civilians on a global scale. Yet when the cameras turn off, these people—forced to leave their homes—often become invisible. Contrary to common belief, most of them remain within their own country, desperately trying to survive and rebuild their lives. They have not chosen this fate, and although they have the same rights as any other citizen, they rarely enjoy the same opportunities. Months or even years can pass before internally displaced persons (IDPs) are no longer in need of support and protection. Finding lasting solutions to this predicament is never straightforward, and displaced populations’ invisibility only worsens matters.

In recent years, the **number of internally displaced persons (IDPs)** has grown significantly, driven by both conflicts and natural disasters. 2015 there were approximately 40.5 million IDPs, but that number has risen steadily to 75.9 million in 2023—nearly doubling over a decade. On the one hand, conflicts have led to a surge in internally displaced persons, from about 40 million at the end of 2015 to over 60 million by the end of 2023, confirming the increasingly significant and protracted nature of wars. On the other hand, natural disasters have also contributed, with the number of displaced persons due to extreme climatic events increasing from around 5 million in 2015 to over 8 million in recent years. This trend indicates that the world faces an increasingly complex crisis in which wars and climate change intertwine, necessitating a more substantial commitment

to finding sustainable, long-term solutions.

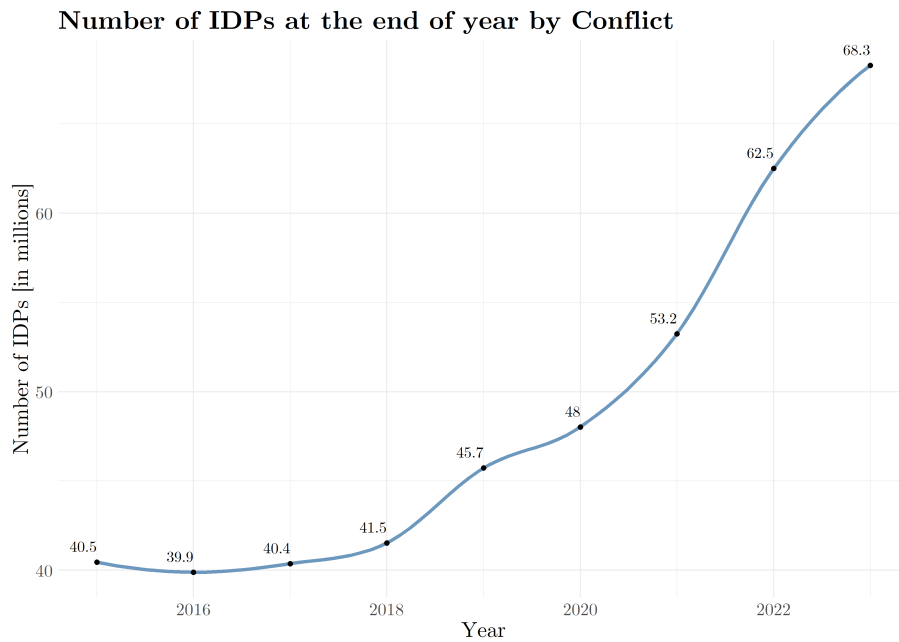


Figure 1.5: IDPs generated by conflict since 2015 Internal Displacement Monitoring Centre [12]

Both conflicts and natural disasters force entire populations to abandon their homes and belongings, often embarking on weeks-long journeys under highly perilous conditions, heading toward an uncertain future. Those who survive usually arrive at an exhausted, hungry, and thirsty refugee camp where the facilities are often overcrowded. The scope of human suffering caused by wars, displacement, and natural disasters is unimaginable.

The need for humanitarian aid unites all affected individuals. Consequently, the study, improvement, and optimization of humanitarian supply chains are assuming growing importance on a global scale.

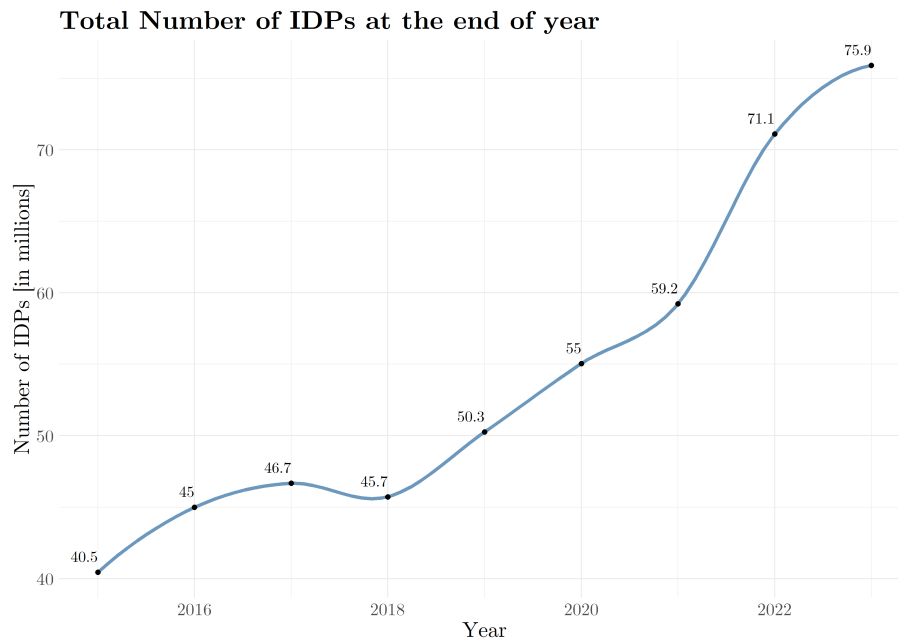


Figure 1.6: Total number of IDPs since 2015 Internal Displacement Monitoring Centre [12]

### 1.1.1. Disaster Definition

Before arriving at a clear and unequivocal definition of the **Humanitarian Supply Chain (HSC)**, it is necessary to clarify some fundamental concepts: disaster, logistics, and supply chain management.

In the context of international cooperation, the notion of **humanitarian aid (HA)** was formally defined by the Council of the European Union:

*“Humanitarian aid essentially refers to the provision of material and logistical support to people affected by natural or man-made disasters, such as armed conflicts, wars, droughts, earthquakes, tsunamis, and hurricanes.”* Council of the European Union [6]

This definition highlights the crucial role of logistics within HA and emphasizes its importance. The following disaster definitions underscore the ability to organize an international network to provide aid and, thus, the significance of supply chain management.

The Emergency Events Database, commonly known as EM-DAT, defines disasters as:

*“situations or events that overwhelm local capacity, prompting a request for external assistance at the national or international level. They are also unpredictable and often sudden events causing significant damage, destruction, and human suffering.”* CRED [7]

A complementary definition is provided by the **International Federation of Red Cross and Red Crescent Societies (IFRC)**:

*“A disaster is a serious disruption to the functioning of a community that exceeds its capacity to cope with its resources. It can be triggered by natural, artificial, or technological hazards and by various factors that influence a community’s exposure and vulnerability.”* International Federation of Red Cross and Red Crescent [14]

Both definitions underscore the potential for destruction, the need for external assistance, the sudden and unpredictable nature of the event, and its dramatic consequences in terms of material damage and human suffering. However, the IFRC highlights a crucial aspect: beyond natural disasters, it explicitly recognizes those caused by humans and technology. This broader perspective is critical in the current global landscape, where wars and internal conflicts threaten communities. Moreover, the definition emphasizes key concepts such as exposure and vulnerability, clarifying that the impact of a disaster depends not only on the event itself but also on the socio-economic and infrastructural conditions of the affected communities. In this sense, a disaster should be viewed as the outcome of a complex interaction between hazard and vulnerability factors, necessitating a broader approach to emergency management.

### 1.1.2. Logistics and Supply Chain Definitions

Regarding the terms “**logistics**” and “**supply chain (SC)**”, much of the literature uses them interchangeably, and many professionals view the difference as purely semantic. Nevertheless, the Council of Supply Chain Management Professionals (CSCMP), formerly known as the Council of Logistics Management, provides distinct definitions:

*“The supply chain — a term now widely used internationally — encompasses all the activities involved in producing and delivering a final product or service, from the supplier’s supplier to the customer’s customer. Supply chain management includes supply-and-demand management, sourcing raw materials and components, production and assembly, warehousing and inventory oversight, order entry and order management, distribution across all channels, and delivery to the customer.”* Council Of Supply Chain Management Professionals [5]

*“Logistics is that part of the supply chain that plans, implements, and controls the efficient and effective flow and storage of goods, services, and related information, from the point of origin to the point of consumption, to meet customer requirements.”* Council Of Supply Chain Management Professionals [5]

In short, the supply chain represents a broad, complex system encompassing every stage of the production and distribution process, from supplier selection to final customer delivery. A supply chain's efficiency hinges on coordinating and optimizing all involved activities, from sourcing raw materials to inventory management and distribution. The true challenge lies in the integrated organization of various actors and processes, capable of adapting to demand fluctuations, containing costs, and at the same time maintaining quality and swift delivery. Today, the supply chain perspective is increasingly global, and real-time synchronization and visibility across different levels are essential to address rising complexity and the market's high expectations.

On the other hand, logistics focuses on the physical and informational flow of goods and services, from procurement to distribution. It entails ensuring that products are transported, stored, and delivered efficiently, meeting customer requirements. Logistics makes supply chain operations possible by coordinating movement, warehousing, and information flows.

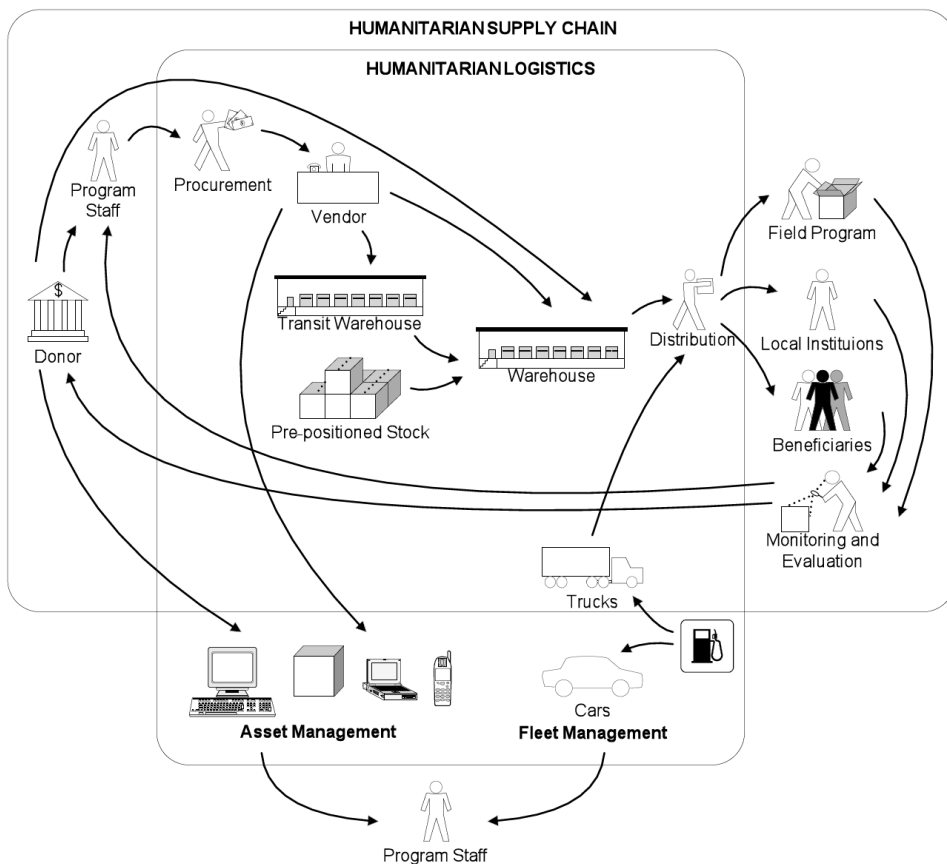


Figure 1.7: Humanitarian Logistics and Humanitarian Supply Chain Flows Howden [11]

These concepts apply directly to the humanitarian sector, where supply chain management and logistics are decisive in disaster and crisis response. In emergencies, speed,

efficiency, and synergy among different stages and actors are crucial to ensuring that aid reaches those in need without delay. The humanitarian supply chain must be able to address specific challenges such as the unpredictability of events, limited resources, restricted access to affected areas, and local requirements management. For this reason, a highly flexible yet well-planned approach is needed, capable of meeting global and regional needs and ensuring that aid is delivered fairly and sustainably. The following definitions highlight the distinctive features and specific functions of the humanitarian supply chain and **humanitarian logistics (HL)**, underlining the methods adopted to manage relief operations during emergencies:

*“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.”* Behl and Dutta [1]

*“Humanitarian logistics 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, with the goal of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking, traceability, and customs clearance.”* Thomas and Kopczak [35]

*“Essentially, for humanitarian actors, logistics is about the processes and systems involved in mobilizing people, resources, skills, and knowledge to help disaster-affected vulnerable people.”* LN Van Wassenhove [18]

The definitions of humanitarian supply chain and humanitarian logistics outline an integrated yet specialized approach to managing resources in emergencies. The humanitarian supply chain focuses on coordinating and carrying out all the activities necessary to provide aid to affected communities, from preparedness to final distribution. As Behl and Dutta [1] points out, this management not only involves procurement and distribution of goods but also the planning and organization of resources to address crisis situations. The definition of humanitarian logistics by Thomas and Kopczak [35] clarifies that, in humanitarian contexts, logistics must be highly efficient and aimed at alleviating suffering among vulnerable populations, through an optimized flow of goods and information. Finally, the quote from LN Van Wassenhove [18] underscores the importance of mobilizing resources, skills, and knowledge, pointing out that logistics is not solely about transportation or storage but also about the strategic coordination of all parties involved to ensure a timely and effective response. Taken together, these definitions reflect the complexity and the

need for agile, well-planned management in emergency response.

## 1.2. IDPs

The Internal Displacement Monitoring Centre (IDMC), established in 1998 as an integral part of the Norwegian Refugee Council (NRC), plays a crucial role in defining and monitoring the flows of internally displaced persons. This institution has developed a widely accepted definition of IDPs, underscoring the complexity of the factors driving displacement:

*“Persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border.”*Internal Displacement Monitoring Centre [13]

The IDMC provides an authoritative and systematic database, offering a clearer view of the phenomenon’s evolution. Research conducted through reports from 2016 to 2024 has highlighted a continuously rising trend: the total number of internally displaced persons has steadily increased, going from about 40 million in 2015 to over 75 million in 2023. This growth, which has nearly doubled the number of IDPs within a decade, clearly signifies not only the worsening of ongoing crises but also the emergence of new conditions of instability that demand more ambitious and coordinated responses. Moreover, the wealth of information collected by the IDMC makes it possible to identify the most common triggering factors, comprehend the extent of the social repercussions, and outline intervention strategies better tailored to the particular features of each regional context.

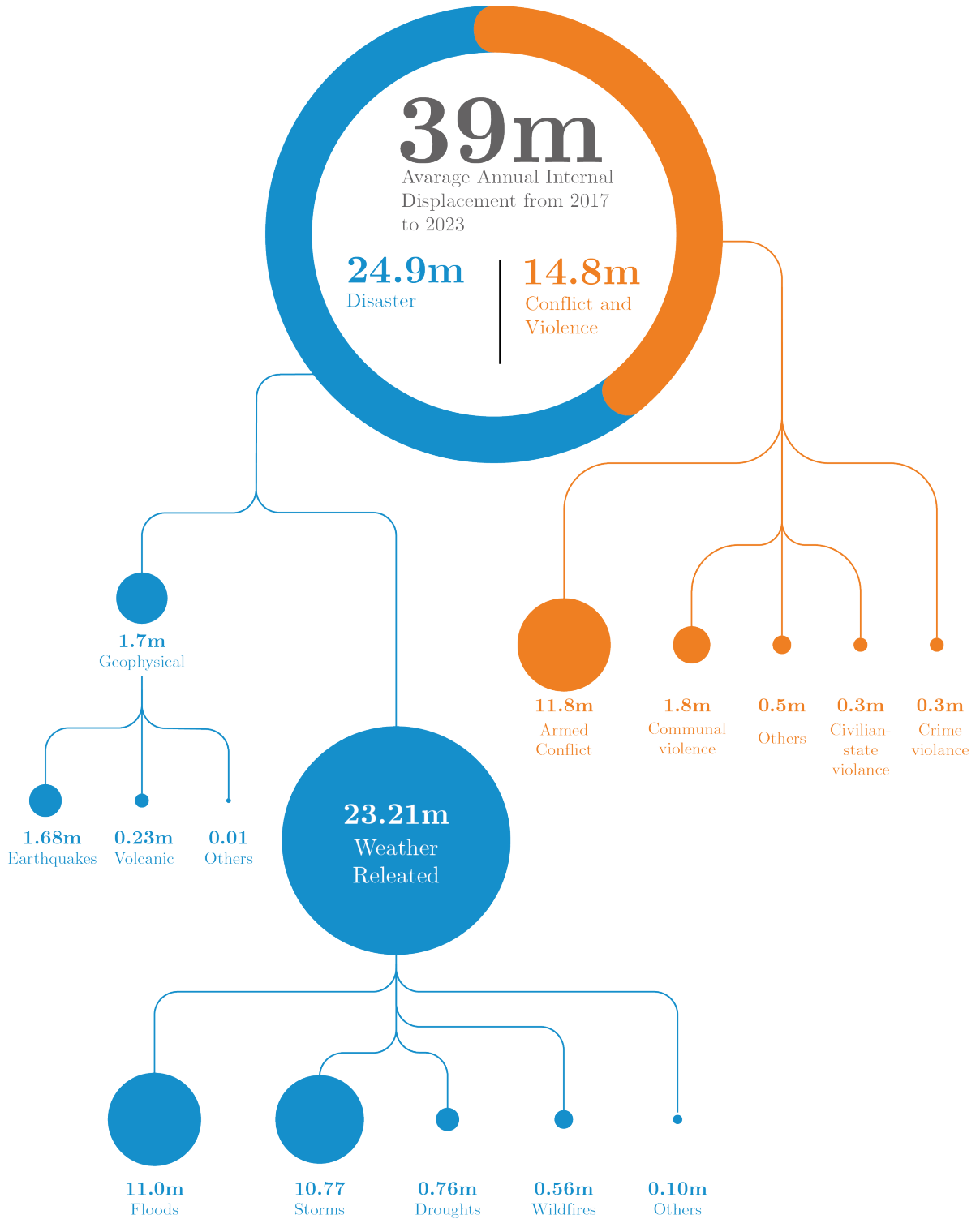


Figure 1.8: IDPs Average of the Last 7 Years by Event

### 1.2.1. Distinction Between Conflict-Induced and Disaster-Induced Displacement

The classification of internal displacement can generally be traced back to two main macro-categories (fig. 1.8): those who flee due to armed conflict and those compelled to leave their homes following natural disasters. Internally displaced persons driven by war often experience prolonged dislocation because they cannot return to their areas of origin as long as insecurity persists or until credible peace processes are initiated. In many cases, armed violence and the destruction of basic infrastructure—hospitals, schools, water networks—further exacerbate the situation, leaving populations in conditions of extreme vulnerability. Conversely, natural disasters can lead to significant yet time-limited exoduses, allowing a relatively quicker return if the affected areas restore essential services and ensure adequate environmental stability.

### 1.2.2. Displacements Induced by Natural Disasters

A detailed examination of displacement linked to natural disasters reveals that extreme meteorological phenomena, such as floods, tropical storms, hurricanes, and typhoons, drive most movements. The increase in the intensity of these events is attributable primarily to climate change: rising global temperatures affect atmospheric currents and the thermal balance of the oceans, spurring the formation of more violent and unpredictable weather systems. This climatic shift expands the number of potentially exposed areas and increases the frequency with which populations must abandon their homes. Moreover, in countries with weaker infrastructure and limited financial resources, the impact of extreme weather events is dramatically higher, as the absence of early warning systems and sufficient defensive measures contributes to the isolation of affected communities.

In addition to meteorological phenomena, wildfires and periods of drought have emerged as further causes of internal displacement. Although their quantitative contribution to the total number of displaced persons is generally lower than floods and storms, these events can devastate entire regions, undermining agriculture, water supply, and the economic sustainability of large rural areas.

Concerning geophysical phenomena, earthquakes remain among the most destructive worldwide. Unlike climate-related events, seismic activities often occur without warning, thwarting any form of preventive evacuation and thereby amplifying the scope of the impact on local populations. Many areas with high seismic activity—such as Southeast Asia, the Middle East, and Latin America—lack adequate infrastructure to withstand

### Average IDPs by type of Meteorological disaster [in million]

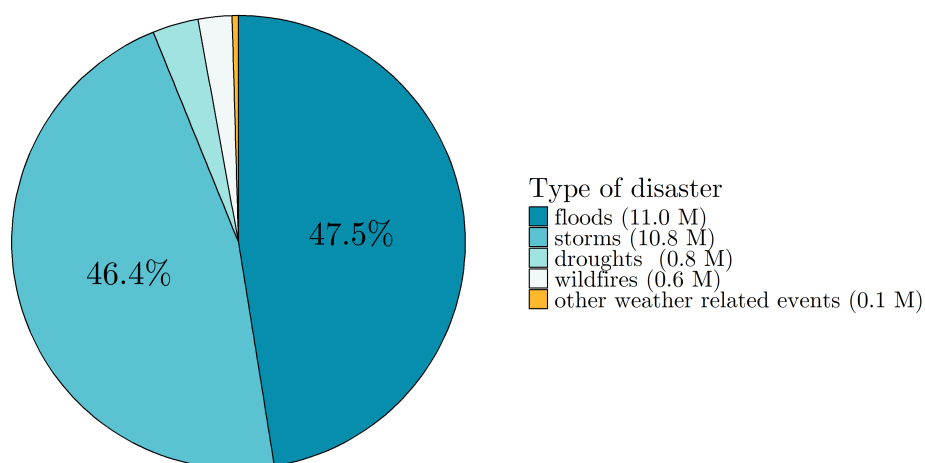


Figure 1.9: Meteorological Disaster Average IDPs

large-magnitude earthquakes. Under such circumstances, entire cities can be razed to the ground in a matter of moments, forcing hundreds of thousands or even millions of people to seek refuge elsewhere. Reconstruction, both material and psychological, can last for years and requires substantial investment, meticulous planning, and a stable political framework capable of managing and coordinating aid efforts responsibly and transparently.

### 1.2.3. Displacements Induced by Armed Conflicts

Regarding armed conflicts, political instability, ethnic or religious tensions, competition over natural resources, and foreign interventions are among the primary catalysts of war. Over the past decade, the gradual intensification of conflict settings has led to a corresponding rise in internal displacement. Notably, according to data gathered by the IDMC, new conflict-related IDPs increased from an average of 6 million in the 2017–2019 triennium to about 20 million in the 2021–2023 period, representing an annual growth of over 26%. This surge shows how the fragility of certain states and geopolitical competition can give rise to massive humanitarian crises.

### Average IDPs by type of Geophysical disaster [in millions]

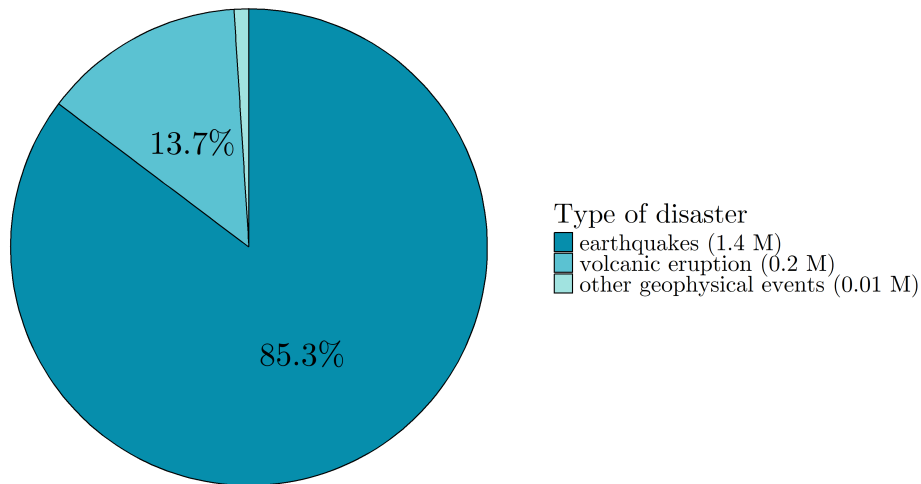


Figure 1.10: Geophysical Disaster Average IDPs

Protracted conflicts—such as those in the Middle East (Syria, Palestine), in several African regions (Sudan, Somalia, Ethiopia, the Democratic Republic of the Congo), and Eastern Europe (Ukraine)—demonstrate how the lack of sustainable diplomatic solutions and credible negotiation mechanisms perpetuates a cycle of violence. In these settings, millions of individuals lose access to essential services (healthcare, education, electricity) and watch as their livelihood opportunities gradually erode. Approximately 80% of conflict-related internal displacement stems from large-scale wars, whereas 14% is associated with smaller-scale but often particularly violent and protracted ethnic clashes. Therefore, the assistance of international and humanitarian organizations is critical to provide protection, logistical support, and, when possible, measures to facilitate the return or resettlement of displaced persons.

Average IDPs by type of Conflict [in millions]

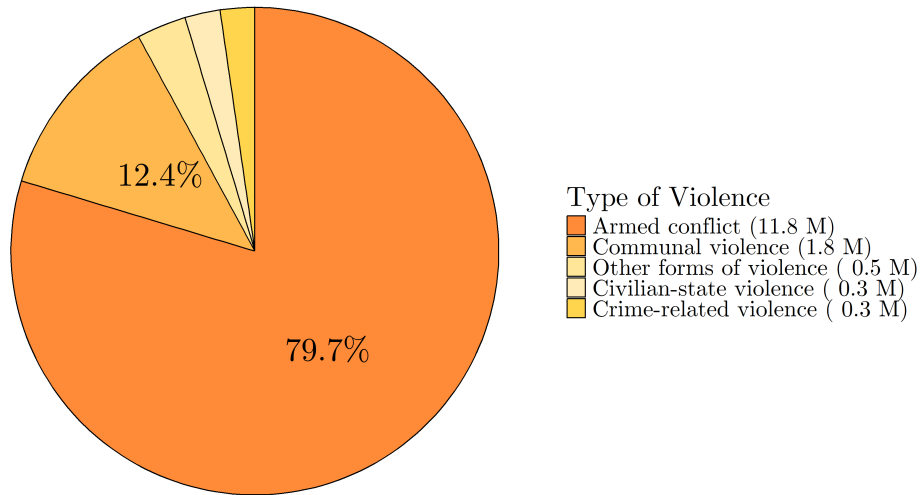


Figure 1.11: Conflict-Related Average IDPs

New IDPs Generate for Year [in millions]

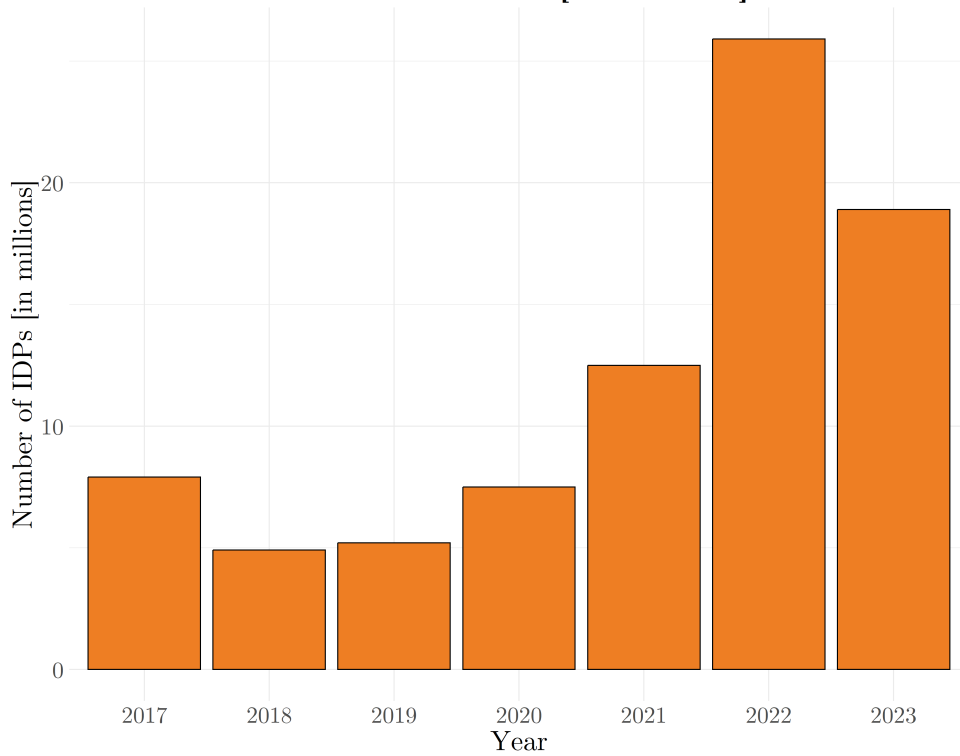


Figure 1.12: New IDPs Generated by Conflict

### 1.2.4. Geographical Distribution of Displaced Persons

The geographical distribution of major internal displacement hotspots highlights a significant concentration in certain macro-regions: Sub-Saharan Africa, East Asia, and Oceania. In Sub-Saharan Africa, structural poverty, often authoritarian governments, ethnic strife, and disputes over critical resources—such as oil, minerals, or arable land—together create an explosive scenario perpetuating instability. Sudan, the Democratic Republic of the Congo, Burkina Faso, Nigeria, Ethiopia, and Somalia represent the tip of the iceberg of a widespread crisis that generates, on average, 10 million new IDPs each year, with devastating repercussions for the entire region.

In East Asia and Oceania, internal displacement is primarily linked to natural disasters, given the geographical location of countries such as Vietnam, the Philippines, and Indonesia, which regularly face large-scale storms and floods. Additionally, seismic faults—such as those between Nepal and China—elevate the risk of intense earthquakes capable of destabilizing entire zones. A unique example is Myanmar, where internal conflict, which escalated in 2021, has compounded an already fragile institutional framework, triggering a spiral of violence that has displaced millions of people.

Map Total IDPs for Country

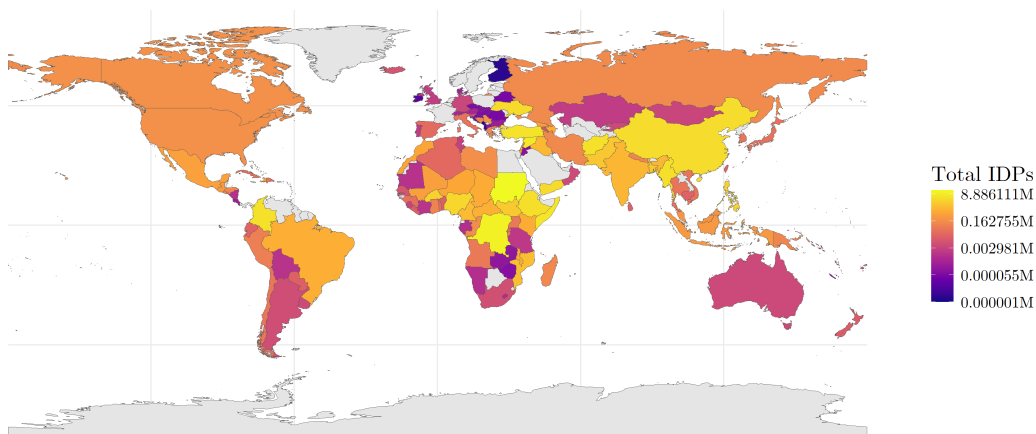


Figure 1.13: Map of IDPs 2023 Internal Displacement Monitoring Centre [12]

Europe is not exempt from challenges, as evidenced by the Russian-Ukrainian conflict, which has produced one of the past decade's most significant internal displacement crises. While in 2015, there were roughly one million IDPs, by 2022, the number of newly displaced had already surged to 17 million, a testament to how quickly security conditions can deteriorate. This emergency has exposed the limits of international coordination and the difficulties neighboring countries face in quickly assimilating such large-scale population movements. In this context, the need for a qualitative leap in cooperation among EU Member States, international organizations, and local authorities becomes clear—both in managing flows and implementing reintegration plans.

Turkey provides another striking illustration of how a single, large-scale event can trigger an immense humanitarian crisis. The severe earthquake of 2023 affected millions of people, rendering vast urban areas uninhabitable and underscoring the necessity of adequate and prompt emergency protocols. The overloading of reception facilities, insufficient earthquake-resistant infrastructure, and the logistical hurdles of accessing remote areas delayed rescue operations, underscoring the importance of a stable governance structure equipped with robust prevention and reconstruction plans. When faced with crises of this magnitude, coordinated international action is vital to prevent long-term repercussions, which could compromise the lives of millions of individuals and impede the country's economic recovery.

In conclusion, the exponential increase in internally displaced persons calls for a global rethinking of policies on prevention, emergency management, and post-crisis reconstruction. Only through synergistic collaboration among governments, supranational bodies, nonprofit organizations, and civil society can sustainable solutions be formulated—ones that encompass immediate humanitarian interventions and long-term measures to foster stability, security, and development in the most affected regions.



## 2 | Literature Review

This part will discuss the primary academic paper referenced in the discussion section. It is essential to have a comprehensive understanding of this information to fully appreciate all the insights and conclusions. To clarify this chapter, it has been divided into two main parts. The first part Section 2.1 presents all the papers used to create a complete picture of today's HSC, including models and articles on how classic business procedures can be implemented in the HSC to improve the number of lives saved. The second part Section 2.2 provides a detailed explanation of the models used in analyzing the factors affecting the HSC.

### 2.1. HSC Analysis

#### 2.1.1. The Applicability Of Commercial SC Models In HSC

In this article, "*The Applicability Of Commercial Supply Chain Models In Humanitarian Supply Chain Thinking*" Duddy et al. [9] attempts to suggest a way to apply some concepts of classical SCM to HSCM. Early attempts to describe humanitarian SC management often relied heavily on commercial SC models. Thomas and Mizushima famously illustrated this by simply substituting the term "customer" with "end beneficiary," reflecting an initial tendency to import commercial concepts with minimal adaptation to humanitarian realities. Over time, however, it has become increasingly recognized that traditional commercial frameworks cannot fully capture the volatility, complexity of stakeholders, and urgent, life-critical objectives that characterize humanitarian operations. The historical foundation of SC thinking was predominantly commercial, epitomized by models focusing on linear flows of materials—such as Forrester's seminal work on the dynamics of SCs. Over the years, the creation of frameworks like the SC Operations Reference (SCOR) model and the process-based models aimed to describe, optimize, and standardize core functions such as procurement, manufacturing, and distribution.

As humanitarian logistics began to be recognized as a distinct domain, many of these models were adapted with limited modifications: for instance, substituting "customer demand"

with “beneficiary needs” or “final product” with “relief items.” Although these adaptations offered initial insights, numerous researchers have pointed out that focusing on discrete processes fails to account fully for the complexities and conflicts inherent in HSC—such as political turbulence, donor-specific requirements, and the unpredictable timing and volume of relief goods. Moreover, in a commercial setting, SC partners usually share profitability, cost savings, or market share as common objectives. HSC, by contrast, often involve multiple non-governmental organizations (NGOs), government agencies, military bodies, and local communities—all operating with varied governance structures, legal regulations, and often competing objectives. Donor influence, infrastructural instability, and volunteer-driven workflows add to these complexities. These nuances have prompted scholars to emphasize that a purely commercial logic can overlook critical factors such as stakeholder relationship management, coordination under uncertainty, and ethical considerations unique to humanitarian operations.

A systematic comparison of extant commercial frameworks highlights several gaps in mapping HSC:

1. **Focus on Process over Context:** Classical process-driven frameworks, such as the SCOR model, outline functions (plan, source, make, deliver, return) but do not inherently accommodate the distinctive political, cultural, or infrastructural complexities found in crisis zones. While valuable for managing tasks such as warehousing or transportation, they overlook the influence of uncertain donor funding streams, beneficiary access issues, and multi-agency coordination.
2. **Reductionist Versus Holistic Views:** Many models assume a linear movement from supplier to customer. By contrast, humanitarian operations function more like networks than chains, incorporating numerous overlapping loops of information, resources, and decision-making nodes. Humanitarian logistics must accommodate push–pull shifts and pivot quickly as field conditions shift. Reductionist approaches that isolate a single component (inventory, for example) cannot provide a comprehensive understanding of the interactions across the entire humanitarian ecosystem.
3. **Stakeholder and Governance Complexity:** Commercial models typically assume strong vertical integration or contractual relationships that help ensure compliance and facilitate data sharing. Yet the humanitarian context brings together NGOs of widely varying sizes, philosophies, and mandates, each with its reporting lines to donors, host governments, or boards of trustees. These participants may not share a unifying profit motive or a single point of control, which complicates the application of frameworks initially designed for more hierarchical SCs.

4. **Humanitarian-Specific Stressors:** Scholars such as Bharosa et al. and Ergun et al. have highlighted that unpredictable onset disasters, conflict zones, and cultural or ethnic biases necessitate SC adaptability that extends far beyond typical commercial considerations. Uncoordinated influxes of well-intentioned but disparate relief efforts may create “supply gluts” of unnecessary commodities while simultaneously leaving critical needs unmet. This highlights the importance of robust coordination and real-time information exchange—factors not always central to commercial models.

### Adapting and Extending Commercial Frameworks

To address these gaps, some researchers have proposed adapted versions of commercial frameworks. For instance, van Wassenhove and Pedraza Martinez advanced a humanitarian-tailored iteration of the SCOR model, acknowledging the heightened role of planning and coordination in disaster relief. Similarly, Blecken emphasized multi-dimensional flows—of materials, finances, and, crucially, information—to account for the intricate data needs in humanitarian contexts. Although these adaptations move closer to capturing humanitarian complexity, scholars widely note that a truly comprehensive framework must incorporate additional layers of stakeholder governance, donor constraints, and real-time coordination.

At the strategic level, Chen and Paulraj’s inclusion of external stakeholders informed some subsequent humanitarian SC research; however, that model was initially geared toward suppliers, manufacturers, and end customers in commercial settings. Cooper et al.’s integration of information flows and process alignment suggests the need for a more holistic perspective. Scholars increasingly suggest that a single, fully integrated humanitarian supply network model is urgently needed—one that moves beyond short-term relief activities to encompass preparedness, disaster risk reduction, recovery, and resilience-building. This approach would acknowledge the unique complexities and ethical imperatives of humanitarian operations while drawing judiciously on insights from commercial SC theories.

To achieve this, future research must:

1. **Capture Multi-Stakeholder Dynamics:** Integrate donors, beneficiaries, NGOs, local governments, military entities, and private sector partners in a single framework that clarifies the influence of each stakeholder’s strategies and needs.
2. **Emphasize Coordination and Collaboration:** Recognize that functional success cannot be divorced from the broader system’s health, where transparency, data-sharing, and synchronized interventions reduce duplication of effort.

3. **Embed Flexibility and Real-Time Adaptation:** Incorporate modules or processes that allow the SC network to pivot rapidly in response to sudden contextual changes.
4. **Incorporate Systems Thinking Tools:** Utilize the Viable System Model to map essential governance and operational functions, and employ the Soft Systems Methodology to address socio-cultural, political, and ethical factors that defy purely quantitative modeling.

### 2.1.2. The Triple A

Supply chain management scholarship has long been grounded in an “efficiency paradigm,” which suggests that minimizing costs, accelerating throughput, and streamlining inventories can provide a distinct competitive advantage. From this perspective, firms often adopt centralized manufacturing, just-in-time deliveries, and tightly controlled logistical operations to achieve short-term gains. However, turbulence in global markets—including geopolitical unrest, pandemics, and sudden fluctuations in consumer demand—has exposed weaknesses in such focused models. Consequently, an increasing advocacy for broader frameworks that enhance both operational sustainability and long-term adaptability emerges.

In *"The Triple-A Supply Chain"* [17] advances a thesis: while cost efficiency and rapid turnaround remain valuable, they must be augmented by three essential pillars—agility, adaptability, and alignment. These attributes, commonly referred to as the “triple A,” serve as the foundation for a more resilient and strategically responsive supply chain. By transcending one-dimensional metrics, the triple-A framework underscores the necessity of swift responsiveness, structural flexibility, and incentive coordination among the various stakeholders in a supply chain.

**Agility**, the first of these pillars, refers to the ability to identify and respond to sudden fluctuations in supply or demand. The literature often cites Nokia’s proactive pivot following a catastrophic fire at a key supplier’s facility, wherein Nokia immediately sourced alternative components, reoriented its production scheduling, and mitigated the downturn in output. By contrast, Ericsson’s slower reaction to the same disruption led to pronounced market share erosion. Such cases illustrate the importance of real-time data exchange, vigorous supplier alliances, and institutionalized contingency planning. While cutting-edge technologies, such as predictive analytics and IoT sensors, can enhance agility by facilitating the early detection of anomalies, organizations must also develop the leadership capacity and decision-making protocols necessary to act promptly on this information.

**Adaptability**, the second tenet, involves long-horizon evolutions in response to external stimuli, ranging from emerging market opportunities to shifts in the global technological landscape. Lucent Technologies, for instance, initially succeeded in establishing Asian production operations that leveraged market growth; however, it failed to continue reconfiguring its supply chain as manufacturing advances and cost structures underwent further transformations. Hewlett-Packard's approach to its printer manufacturing exemplifies a more sustained form of adaptability. By transitioning operations to Singapore for economies of scale and subsequently embracing an outsourced production model once the technology matured, HP demonstrated an ongoing commitment to readjusting its production and distribution architecture as market conditions evolved. Beyond geography, adaptability encompasses product design, sourcing strategy, and distribution network optimization to ensure that firms remain competitive in dynamic environments.

The third pillar, **alignment**, emphasizes the harmonization of objectives and incentives among supply chain participants. Even highly efficient chains can falter when local stakeholders focus on narrow outcomes, such as passing on inventory costs to upstream or downstream partners. For instance, vendor-managed inventory arrangements, while potentially beneficial to manufacturers, may burden suppliers unduly if they shoulder disproportionate risks. Saturn circumvented such misalignment by instituting metrics that equitably reward both manufacturers and retailers, thereby fostering an ecosystem in which shared goals translate into congruent operational behaviors. According to the broader literature, successful alignment requires comprehensive communication channels, equitable allocation of gains, and clear delineation of roles, ensuring that no segment of the network is either marginalized or disproportionately taxed.

Over the past two decades, global markets have tested the viability of the triple-A framework. Recurrent shocks—including trade disputes, environmental crises, and public health emergencies—have highlighted the fragility of supply networks when they are designed solely for efficiency. Organizations that deliberately embed agility, adaptability, and alignment, however, appear better equipped to weather unforeseen disruptions while simultaneously capitalizing on emergent opportunities. Big data analytics, for example, can advance agility through improved demand forecasting and near-real-time anomaly detection. Meanwhile, nearshoring or reshoring strategies represent an adaptive mechanism when transcontinental operations become precarious. Lastly, alignment may necessitate innovative contractual and financial arrangements to ensure that each party in the network has vested interests in both short-term performance and sustained market success.

Strategically, the triple-A framework challenges the conventional assumption that economies of speed and cost automatically produce sustainable differentiation. While lean method-

ologies and continuous improvement can enhance operational precision, they do not necessarily engender resilience in the face of disruptive events. Agility enables the rapid recalibration of day-to-day processes, particularly in sectors confronting volatile consumer preferences, such as fast fashion and consumer electronics. Adaptability fosters the foresight and flexibility necessary to reconfigure the supply chain architecture in response to macro-level shifts in markets, technologies, and regulations. Alignment, in turn, prevents the detrimental outcomes associated with siloed decision-making and misaligned incentives by ensuring that all contributors work in concert toward mutually agreed-upon objectives.

### 2.1.3. Humanitarian logistics in disaster relief operations

Kovács and Spens in "*Humanitarian logistics in disaster relief operations*" [16] establish humanitarian logistics as a discipline that transcends conventional understandings of supply chain management, placing it firmly at the core of comprehensive disaster relief efforts. Their work contends that effective logistics orchestrates a balance of financial input, infrastructural capacity, and operational procedures, all geared toward meeting urgent humanitarian needs. By conceptualizing logistics as a pivotal facilitator of timely and cohesive disaster interventions, they highlight the extent to which well-structured processes can support mission success in complex and variable contexts.

In their discussion of disaster relief, they delineate three major phases—preparedness, immediate response, and reconstruction—and elucidate the operational and strategic imperatives specific to each. Within preparedness, the authors emphasize proactive measures and resource allocation, suggesting that organizations undertake detailed risk analyses to pinpoint critical pressure points in an emergent situation. This preparatory work involves forging alliances with both governmental entities and local communities well ahead of a crisis, ensuring that essential supplies, such as pharmaceuticals, water filtration units, and non-perishable foodstuffs, are readily accessible. One dimension they stress is the need for specialized training of logistics personnel, who often operate under precarious conditions where conventional best practices for transportation or inventory oversight may quickly become obsolete.

During the immediate response phase, Kovács and Spens note that uncertainty and information asymmetries can derail even the most elaborate plans. Natural disasters may damage primary infrastructure routes, creating bottlenecks that jeopardize on-time delivery of critical items. Where conflict is involved, restricted access to certain regions may necessitate negotiations with multiple authorities or require that agencies establish alter-

native shipping corridors. In these rapidly evolving scenarios, the authors identify agility and real-time adaptability as paramount. They describe how relief organizations must swiftly pivot to new transport modes, implement last-mile distribution innovations, and coordinate with psychosocial support teams to ensure survivors not only receive tangible relief items but also the less tangible forms of assistance crucial to emotional and mental well-being. By placing the concept of agility at the forefront, the authors underscore the role of rapid decision-making mechanisms, agile inventory management, and on-site resource reallocation to align supply with perpetually shifting demand.

When relief transitions to reconstruction, their examination turns to the longer-term undertakings required for robust community recovery and resilience. Kovács and Spens note that logistical decision-making in this phase must incorporate socio-economic nuances, such as the availability of local labor, the status of existing infrastructure, and the diverse cultural norms that govern settlement patterns or building requirements. Specialized shipments—such as heavy machinery for debris removal, construction materials suited to the region’s climate, and replacement parts for crucial utilities—necessitate an approach that melds logistical efficiency with local input and expertise. To that end, the authors discuss the merits of embedding personnel who can facilitate communication with community stakeholders, ensuring that rebuilding efforts do not inadvertently undermine traditional practices or create dependencies that hamper self-sufficiency. This perspective highlights a progression from crisis management to a more nuanced, context-specific integration of humanitarian aid with local development priorities.

The authors examine a wide-ranging array of stakeholders and underscore the need for a unifying logistical architecture capable of encompassing their divergent objectives, mandates, and operational styles. Large donors or transnational agencies may demand performance metrics or extensive compliance documentation, while small, community-based organizations often lack the administrative capacity to fulfill such requirements. Kovács and Spens advise establishing clear roles and a common logistical framework that orchestrates the movement of goods and services even when stakeholders differ in scale or strategic orientation. They propose that effective coordination measures can significantly reduce friction, avoid duplication of efforts, and channel resources more productively, thereby amplifying the collective impact of relief and recovery operations.

In addressing the critical challenge of forecasting, they highlight how humanitarian logistics must accommodate significant volatility. Unlike commercial supply chains that rely on historical demand data for planning, humanitarian operations frequently contend with abrupt surges in need, often in regions where existing data is sparse or unreliable. For instance, a population displaced by conflict can balloon unexpectedly if hostilities escalate

in neighboring provinces, or if a natural disaster renders certain areas uninhabitable. To mitigate potential disruptions, Kovács and Spens detail strategies such as pre-positioned contingency stocks, a modular approach to allocating warehouse space, and flexible transportation arrangements capable of rapid scaling. Adopting these methods allows responders to pivot resources in real time, guided by updated field intelligence and beneficiary feedback, thus minimizing costly mismatches between supply and demand.

Another significant aspect they highlight is the multifaceted sociopolitical environment in which humanitarian logistics must operate. The authors remark that political tensions, local power dynamics, and cultural sensitivities can hamper the smooth flow of aid if not anticipated from the outset. For example, delivering specialized medical equipment could require navigating a complex permit structure or liaising with multiple administrative bodies, each imposing its own regulations. Such constraints necessitate that logistical teams not only excel at technical functions—like routing or inventory management—but also master the intricacies of negotiation and relationship-building. Kovács and Spens imply that well-honed communication channels, possibly involving robust IT platforms for data sharing, are integral to bridging these divides and sustaining continuous collaboration between field personnel, donor headquarters, and local authorities.

Alongside these environmental and operational complexities, their framework underscores the necessity of coherent feedback loops that allow for iterative adjustments. Kovács and Spens suggest that an organization's institutional learning grows incrementally through each crisis, thereby informing more refined logistics blueprints in subsequent emergencies. This learning curve feeds directly into improved coordination protocols, more resilient infrastructure designs, and deeper, more reciprocal relationships with local communities—ultimately enabling a more dynamic management of resources under rapidly changing conditions. Their conceptualization of logistics as an iterative system signifies that each disaster response, whether successful or hindered by setbacks, contributes to a broader base of practical knowledge essential for refining humanitarian supply chain methodologies.

Finally, their conclusion posits humanitarian logistics not just as an operational or tactical field, but as a driver of strategic outcomes that can help or hinder the broader recovery trajectory. By illuminating how logistics intersects with preparedness, response, and reconstruction, the authors situate it at the cross-section of immediate relief actions and sustained development goals. They reinforce that a thorough appreciation of local contexts, combined with methodical contingency planning and agile practices, underpins an effective humanitarian logistics apparatus. In doing so, they underscore the transformative potential of logistics to act as the connective tissue among disparate stake-

holders—be they governmental, nongovernmental, or local—while also fostering resilience within affected populations. Over time, these accumulative efforts can shift humanitarian interventions beyond temporary band-aid solutions toward integrated frameworks that actively contribute to both short- and long-term stability.

#### 2.1.4. Analytic Hierarchy Process

Decision-making in complex environments often requires careful consideration of multiple criteria—some objective and tangible, others subjective and intangible. The Analytic Hierarchy Process (AHP), developed by "*The analytic hierarchy process—what it is and how it is used*" Saaty [32] in the 1970s, is a systematic method designed to address such multidimensional problems. It provides a framework for organizing the criteria, comparing them pairwise, and synthesizing these comparisons to derive overall priorities or rankings.

A key strength of AHP lies in its ability to quantify subjective judgments and integrate them with objective data, thereby generating ratio scales. By breaking down the problem into smaller, more manageable elements and comparing them in a methodical way, AHP accommodates the limits of human cognition without sacrificing the richness of expert knowledge.

One of AHP's principal objectives is to convert qualitative and intangible preferences into numerical values that reflect the relative priority of criteria or alternatives. These measurements are expressed on a ratio scale, meaning that instead of merely providing vague expressions, a decision-maker can state, "Option X is five times more important than Option Y." While subjective judgments are unavoidable in many real-world decisions, AHP encourages verification of their internal consistency, allowing for a certain degree of inconsistency but also providing a Consistency Index (C.I.) to monitor its extent. Moreover, since AHP transparently organizes the comparisons among criteria and alternatives, decision-makers can easily trace back the final ranking to the specific judgments and criteria that had the greatest impact on the outcome.

The first step in applying AHP is to decompose the decision problem into a hierarchy of levels or groups of related elements. Pairwise comparisons are then introduced: two elements are evaluated with respect to their "parent" criterion in the higher level, thus producing a judgment matrix. If, for instance, there are  $n$  elements to be compared, one constructs an  $n \times n$  matrix  $A$ , whose entries  $a_{ij}$  express how many times element  $i$  is more important than  $j$ . According to the reciprocity axiom,  $a_{ij} = \frac{1}{a_{ji}}$ . If element  $i$  is moderately more important than  $j$ , then  $a_{ij} = 3$ , implying  $a_{ji} = \frac{1}{3}$ .

To guide such judgments, the fundamental 1–9 scale is often used:

- 1 → Equal importance
- 3 → Moderate importance
- 5 → Strong importance
- 7 → Very strong importance
- 9 → Extreme importance

Once the judgment matrix  $A$  is constructed, local priorities—i.e., the relative weights of the elements with respect to their parent criterion—are obtained by finding the principal eigenvector of  $A$ . This eigenvector, normalized so that the sum of its components equals 1, represents the relative weights or priorities.

Because complex comparative judgments can introduce inconsistencies, AHP proposes a verification based on the condition

$$a_{ij} \times a_{jk} = a_{ik} \quad \text{for each triplet } (i, j, k).$$

A matrix that perfectly satisfies this relationship has a principal eigenvalue  $\lambda_{\max} = n$ . In practice, it is common to find  $\lambda_{\max} > n$ , and the difference  $\lambda_{\max} - n$  is used to measure inconsistency:

1. **Consistency Index (C.I.)**

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n - 1}. \quad (2.1)$$

2. **Consistency Ratio (C.R.)**, which compares the C.I. with an average index (R.I.) derived from random reciprocal matrices:

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}}. \quad (2.2)$$

If  $\text{C.R.} \leq 0.10$ , the level of consistency is deemed acceptable; if C.R. significantly exceeds 0.10, it is necessary to re-examine the judgment matrix to identify and correct possible inconsistencies.

The R.I. value is typically obtained by averaging the Consistency Index of a large number of randomly generated reciprocal matrices (maintaining the reciprocity property) for increasing dimensions  $n$ . In the literature, tables report the average R.I. values for different  $n$ . Those provided by Saaty are:

n	1	2	3	4	5	6
<b>Random Consistency Index</b>	0.00	0.00	0.58	0.90	1.12	1.24

Table 2.1: Random Consistency Index [32]

Because these values derive from analyzing many randomly generated matrices, the R.I. provides a statistical reference: by comparing our C.I. to the R.I., we can determine whether our judgment matrix deviates excessively from “random” behavior or if it is sufficiently consistent.

AHP’s systematic approach allows decision-makers and stakeholders to understand in detail how each priority or ranking is determined, enabling them to trace from the final results back to the individual comparisons that produced them. Furthermore, pairwise comparison and consistency measurement help detect and correct inadvertently contradictory preferences, making decisions more robust and reliable.

When aggregating the judgments of multiple individuals, the geometric mean is often used. This method proves particularly useful in processes involving multidisciplinary teams or complex decision-making bodies, as it integrates diverse perspectives while preserving the internal weight structure contributed by each participant.

Over the years, AHP has demonstrated its effectiveness in a wide variety of contexts: from strategic planning to resource allocation, from technology selection to more routine choices such as evaluating a degree program or choosing a car. Its ability to handle both quantitative and qualitative factors with ease makes it an extraordinarily versatile tool.

## 2.2. Factors

### 2.2.1. Delphi Method

The Delphi method is a structured, as described by the *"The Delphi method as a research tool: an example, design considerations and applications"* Okoli and Pawlowski [27], iterative group communication process designed to generate consensus from a panel of selected experts on complex problems. Initially developed by the RAND Corporation in the 1950s, Delphi was conceived to enhance expert forecasting and decision-making by mitigating the drawbacks of confrontation, such as undue influence, groupthink, or reluctance to revise initial viewpoints. In its classical form, Delphi researchers administer multiple rounds of questionnaires to a group of experts, summarize the interim findings anonymously, and iteratively feed these results back to the participants until a satisfactory

level of consensus emerges.

## Foundations and Key Characteristics of the Delphi Method

A defining feature of Delphi is its use of structured anonymity among experts. Whereas face-to-face discussions can lead to conformity or dominance by outspoken participants, the Delphi method preserves the independence of judgment by keeping respondents anonymous to one another. Experts complete questionnaires individually, and the facilitator or research team analyzes and summarizes the input, redistributing aggregate findings in subsequent rounds. As Okoli and Pawlowski note, this approach promotes reflective reconsideration of positions without exposing respondents to social or hierarchical pressures.

Delphi's success hinges on the repetition of feedback loops. In each round, participants receive statistical or descriptive summaries of the panel's prior responses, which often include median rankings, mean scores, and/or qualitative rationales from their peers. They are then invited to revise or confirm their initial assessments in light of the group data. The method's strength lies in this repeated process, which tends to narrow opinion gaps and minimize random variation. Over successive rounds, panelists typically converge on stable rankings or judgments.

Because Delphi aims to capture judgmental insights that would otherwise be difficult to quantify, the selection of credible, knowledgeable participants is critical. Unlike conventional surveys that rely on representative sampling from a broad population, the Delphi method targets individuals with recognized expertise. This expert-oriented approach compensates for smaller sample sizes. Thorough vetting of candidates ensures that participants can both articulate informed perspectives and benefit from each other's expertise once feedback begins.

Beyond forecasting or issue prioritization, Delphi can also inform theory development in at least four ways:

### 1. Variable Identification

Brainstorming rounds often yield constructs and conceptual variables that may be tested in subsequent empirical work, paving the way for more focused hypotheses.

### 2. Construct Definition

Iterative validation of item definitions ensures that terms reflect both practitioner and researcher perspectives, enhancing construct clarity and boosting external validity.

### 3. Cause-and-Effect Elaboration

Encouraging experts to justify their item rankings illuminates possible causal pathways among factors, providing fodder for emergent theoretical propositions.

### 4. Practice-Informed Relevance

Because Delphi relies on in-depth domain expertise, the resulting theories often possess greater relevance and applicability to real-world settings, thereby bridging the research–practice divide.

## 2.2.2. Exploring CSFs of HSCM in flood disaster management

HSCM has garnered increasing attention due to the growing number of disasters. Whereas traditional SCM research has historically focused on commercial operations, the distinctive urgency, unpredictability, and human-centric nature of disaster relief have motivated a separate strand of literature addressing disaster management, humanitarian logistics, and, more broadly, HSCM. Within this strand, "*Exploring critical success factors (CSFs) of humanitarian supply chain management (HSCM) in flood disaster management (FDM)*" [8] work makes a key empirical contribution by examining the critical success factors (CSFs) of HSCM in the specific context of flood disaster management (FDM). HSC is typically defined as the process of planning, implementing, and controlling the efficient flow of relief items, information, and other resources from the point of origin to disaster-affected areas to alleviate suffering. In contrast to commercial supply chains, HSCs entail high levels of uncertainty, as relief operations often take place under damaged infrastructure, volatile funding sources, and unstable demand patterns. Accordingly, agility, responsiveness, and close collaboration with stakeholders are considered core principles in humanitarian logistics.

The CSFs in the context of project and operations management emphasize specific elements that, if effectively addressed, lead to higher success rates. Although literature on CSFs exists in commercial SCM, it suggests that these factors should be adapted carefully for humanitarian operations because of the fundamental differences in objectives, stakeholder networks, and the volatility of the operating environment. In flood-prone regions, particularly in sub-Saharan Africa, logistical difficulties stemming from underdeveloped infrastructure, unpredictable funding, and cultural considerations add layers of complexity. Because floods often happen on a cyclical or seasonal basis—yet sometimes with very high intensity—preparedness through prepositioning of relief items and advanced planning becomes crucial. Additionally, developing strong administrative structures, training relief workers, and engaging local communities and government agencies have been observed to

enhance the effectiveness of flood relief efforts.

Research indicates that many African countries, including Ghana, adopt reactive—rather than proactive—flood management measures. Shortages in funding and underinvestment in infrastructure obstruct efficient relief and recovery operations. The African Union and the New Partnership for Africa’s Development have advocated for more substantial institutional capacity and comprehensive risk-reduction policies; however, implementation remains inconsistent. Scholars consistently emphasize the importance of establishing frameworks that incorporate local stakeholders, civil society, and governmental agencies for both preventive measures. Stakeholder engagement is particularly vital in flood contexts, where local knowledge—such as identifying flood-prone zones or understanding community evacuation behaviors—can inform effective relief deployment. For instance, aligning with stakeholder theory, communities, funding agencies, government units, and humanitarian organizations act as interdependent actors. Successful supply chain interventions often depend on proactive collaboration, resource sharing, and trust within these networks.

Despite growing recognition of the need for systematic HSCM research, the literature remains thin on *empirically* validated success factors in humanitarian operations—particularly for flood disaster management. Much of the work to date has involved conceptual models or theoretical expositions; however, relatively few studies provide robust, real-world data on the factors that practitioners find most critical. Within the African flood context, there is also a need to integrate socio-cultural variables—such as community beliefs and attitudes toward disasters—into HSCM frameworks. Flooding can carry religious or cultural connotations, influencing how local populations respond to warnings and relief measures. Additionally, the infrastructural gap—encompassing roads, communication systems, and storage facilities—remains a significant operational challenge. Addressing these multifaceted constraints requires a holistic assessment of management practices, technology adoption, and administrative policies.

Therefore, fills a significant gap by systematically identifying and validating the key success factors for humanitarian supply chain operations in flood-disaster-prone environments. By highlighting the roles of stakeholder involvement, infrastructure, training, and other organizational practices, this study moves the conversation toward evidence-based strategies for more effective flood disaster response.

### 2.2.3. Papadopoulos Model

The Papadopoulos Model is a framework presented in the paper entitled “*The role of Big Data in explaining disaster resilience in supply chains for sustainability*” [31], published in the *Journal of Cleaner Production* on April 12, 2016. It aims to identify the core principles in humanitarian emergency management, placing at its center the synergy between the public and private sectors. Such synergy is enabled by creating an environment of trust and ensuring an effective flow of information. This collaboration reinforces the resilience of supply chains and critical infrastructure, essential elements for a timely and efficient response to crises. Their impact directly influences the ability of communities to cope with emergencies and the sustainable management of available resources.

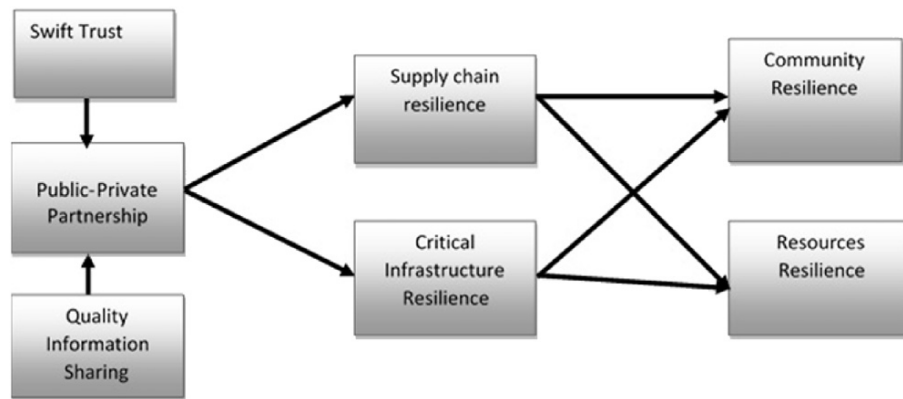


Figure 2.1: Papadopoulos Model Schema [31]

According to this model, in the context of the **humanitarian supply chain**, both resilience and operational effectiveness depend on the **partnership between the public and private sectors**. The public sector—comprising government institutions, international organizations, and regulatory bodies—is responsible for facilitating access to affected areas, regulating operations, and ensuring respect for human rights. In contrast, the private sector and NGOs provide logistical resources, technical expertise, and operational capabilities. Emergencies, whether caused by natural disasters, conflicts, or prolonged humanitarian crises, demand rapid and efficient responses, often under conditions of uncertainty and resource scarcity. Managing these situations is extraordinarily complex, as they involve stakeholders with different objectives, constraints, and resources. A key to effective intervention is the ability to quickly establish **immediate trust (Swift Trust)** among all parties involved. In a critical context, there is no time to build trust over the long term: partners must be able to rely on one another from the outset.

Another essential element underpinning partnerships between the public and private sec-

tors is **the sharing of high-quality information**, enabling data-driven decision-making that relies on accurate and up-to-date information. Transparency in information flow among partners helps optimize inventory management, avoid waste, and shorten response times. In the past, the lack of precise information about local needs led to ineffective aid distribution: some locations received excessive supplies, while others were left without support.

The partnership between the public and private sectors, supported by reciprocal trust and information sharing, helps reinforce both the resilience of the humanitarian supply chain and the resilience of critical infrastructure, thereby improving the capacity to adapt and recover rapidly from disruptions. A **resilient supply chain** must be able to withstand unexpected events such as stock destruction, border closures, or fuel shortages, swiftly finding alternative solutions to ensure aid delivery within an appropriate timeframe. At the same time, strengthening the **resilience of critical infrastructure**—which includes transportation networks, communication systems, energy grids, and healthcare facilities—is essential. Even the best-planned humanitarian operations can fail if roads become impassable or communication systems are inoperative.

The synergy between an efficient supply chain and robust infrastructure has a direct impact on **community resilience**, that is, the ability of affected populations to cope with and overcome emergencies. When a community has access to adequate resources—such as food, potable water, energy, and medical care—it recovers more quickly. Another crucial aspect is the **resilience of resources**, ensuring continuity in the provision of essential goods and minimizing interruptions that could jeopardize humanitarian operations. Effective stock management, supported by advanced monitoring systems and close collaboration between the public and private sectors, helps prevent waste and distribute aid intelligently, based on identified needs. However, resources are not limited to material goods: volunteers play a fundamental role. The training of field personnel, ongoing support, and the ability to adapt to unforeseen situations all improve emergency response and contribute to a more sustainable intervention in the long term.

All these components are interdependent: without trust and information sharing, partnerships between the public and private sectors become ineffective; without robust infrastructure, aid distribution is compromised; and without sustainable resource management, the entire supply chain risks grinding to a halt. The model under study therefore underscores the importance of an integrated and coordinated approach to humanitarian supply chain management, in which cooperation among different stakeholders and resource optimization are crucial for ensuring an effective and sustainable response to emergencies. Investing in preparedness and the resilience of the supply chain not only enhances the

effectiveness of humanitarian interventions but also mitigates the impact of crises on the most vulnerable populations, contributing to a more rapid and lasting recovery.



# 3 | Methodology

In this chapter, we will outline the methodology employed throughout the discussion. Before proceeding, clarifying the research's motivations and objectives is essential. The primary aim is **to determine the key factors that influence HSC**.

This question arose following another research question dedicated to optimizing logistics flows in the HSC. The first step was to collect data on material handling. It has been decided to develop questionnaires and an interview template for practitioners from different NGOs to find data and information about the procedures that would be analyzed. Nevertheless, during the interviews, it was discovered that numerous organizations either lacked the requisite data or possessed it in a highly aggregated or variable format, as the strategies employed to address emergencies were primarily based on the direct experiences of the responders. Only a few more prominent NGOs, such as the **World Food Programme (WFP)**, had comprehensively analyzed data.

From these findings, the idea emerged to reframe the research question to identify the factors influencing HSC more clearly and to provide recommendations for improving operational procedures and practices to save as many lives as possible. On this solid basis, further deepening the research will be possible by adopting even more refined methodologies. In summary, this work aims to identify these factors and propose best practices or models for improving the management and control of the HSC.

## 3.1. Interviews

The first phase of the research entailed conducting structured interviews with a selected group of professionals and volunteers from a diverse set of humanitarian organizations. This approach was chosen to capture the context-specific, tacit, and often experience-based insights that tend to remain hidden when relying solely on secondary or highly aggregated data. Previous attempts to gather quantitative data, such as shipment volumes, inventory records, and lead times, revealed notable gaps: some organizations lacked comprehensive reporting systems, whereas others either limited access to their internal

data due to security or privacy concerns or shared it only in a heavily aggregated form. Consequently, interviews became the primary means of accessing richer, more nuanced operational and logistical knowledge.

The overarching objective of this interview phase was twofold. First, it sought to understand the depth and breadth of HSC operations through the lived experiences of practitioners engaged in the field. Second, it aimed to identify key operational challenges—such as logistics bottlenecks, variable supplier performance, or the impact of donor constraints—that raw quantitative metrics cannot easily capture. The guiding principle was that researchers could access tacit knowledge critical for strengthening HSC processes in conflict and disaster contexts by directly conversing with frontline staff and logistics coordinators.

Participant recruitment occurred over several weeks. An initial pool of more than forty organizations was generated through literature scans, peer researchers' references, and humanitarian sector professional networks. These organizations varied in size (from large, international NGOs to smaller, more localized agencies) and specialty (e.g., organizations primarily focused on food distribution, medical relief, shelter provision, or child welfare). This intentional diversity ensured that different operational models, funding structures, and logistical approaches were represented.

## Interview Structure and Design

A structured interview guide was developed to ensure methodological consistency and facilitate comparisons across organizations (see appendix A.1 for the complete interview template). The guide featured a blend of fixed-response and open-ended questions:

1. **Fixed-Response Questions:** These sought basic organizational information (e.g., average annual budget, typical scale of operations, staffing levels) to establish a baseline understanding of each NGO's scope. When available, respondents were also asked to provide quantitative metrics such as shipping volumes and average lead times.
2. **Open-Ended Questions:** These probes invited participants to elaborate on core areas of HSC operations:
  - *Preparedness and Planning:* How do organizations plan for sudden-onset or protracted crises? Are there any region-specific readiness measures?
  - *Emergency Response Protocols:* What processes govern immediate responses following natural or conflict-related disasters, and how are decisions made un-

der intense time pressures?

- *Inventory Positioning and Warehouse Management:* Do organizations use pre-positioned stocks, and how do they adapt storage strategies in varying geographical or security contexts?
- *Supplier Relationships and Coordination:* How do NGOs select and manage supplier partnerships, especially amid unstable or crisis-prone regions?
- *Key Performance Indicators:* Which performance metrics are tracked internally, and how do they inform resource allocation or strategic planning?
- *Risk Assessment:* How do organizations identify and mitigate logistics risks—such as road blockages, fragile peace agreements, and limited air cargo access—before and during missions?

The open-ended nature of these questions allowed interviewees to integrate their perspectives, experiences, and real-time observations, often illuminating issues unaddressed in organizational reports. Moreover, this format allowed participants to detail context-specific challenges, such as regulatory hurdles at border crossings, donor-mandated requirements, or cultural sensitivities affecting local partnerships.

Prior to each interview, a brief information sheet outlining the study's purpose was shared with participants. Interviews were conducted face-to-face whenever feasible; online video conferencing platforms were utilized when geographical or scheduling constraints prevented in-person meetings. Each session lasted between 45 and 90 minutes, depending on participants' availability and the complexity of their roles. Researchers obtained informed consent at the start of each session, clarifying that the data would be used exclusively for the thesis purposes. Copies of the interview guide were provided during face-to-face sessions, enabling participants to follow the question flow. In virtual settings, the guide was shared via email beforehand.

A core output from each interview was the identification of variables and indicators relevant to HSC performance. Participants were explicitly asked to suggest or validate a range of factors for a ranking tool that was being developed to evaluate significant global crises over the past decade. Their expert input enabled the research team to refine this tool by incorporating variables NGOs viewed as most pertinent to success or failure in different operational contexts.

Additionally, interviewees were invited to share any available quantitative data from primary emergency missions over the last ten years. Although many organizations were limited by donor-imposed data privacy stipulations or internal security protocols, several

participants provided high-level indicators, operational notes, and aggregated data tables. This information was integrated into a broader dataset used for the factor analysis phase of the research. In cases where data were unavailable or highly aggregated, participants' qualitative comments (e.g., areas of chronic bottlenecks or best practices they found crucial in large-scale emergencies) proved equally insightful.

Ethical best practices guided every step of the interview process. Before collecting information, participants were informed in writing and orally about the study's aims and their right to withdraw. Extra caution was taken in discussions about politically sensitive topics, such as a government's role in conflict areas or security concerns in war-torn regions. In such instances, participants were reminded that they were not obligated to disclose information that could compromise ongoing operations.

### 3.2. General HSC Analysis

After gathering valuable insights from interviews with professionals involved in humanitarian logistics, the HSC analysis was developed using a clear and structured approach. The goal was not just to describe how HSCs work, but to understand how they change and function during emergencies caused by natural disasters or conflicts. To facilitate this, the HSC analysis in Chapter 4 is divided into six subsections, each addressing a specific thematic dimension of humanitarian supply chains. The first subsection, "**Humanitarian Supply Chain Evolution**" provides an overview of how HSCs have developed in response to global crises, outlining key shifts in strategy, technology, and logistics priorities. The second subsection, "**Collaboration Model**" examines the importance of partnerships, coordination, and cooperation among NGOs, international organizations, and donors. The third subsection, "**Phases of HSC**" draws on the framework by *Humanitarian Logistics in Disaster Relief Operations* [16], of Kovács and Spens, to describe the three main operational phases: preparedness, immediate response, and reconstruction. The fourth subsection, "**Type of NGOs**" explores the different roles and operational profiles of NGOs, differentiating between local, national, and international actors. The fifth subsection, "**HSC Common Stakeholders**" identifies and explains the interests, roles, and interrelations of typical stakeholders involved in humanitarian logistics. Finally, the sixth subsection, "**From Supply Chain Management to Humanitarian Supply Chain Management**" compares commercial and humanitarian supply chain principles, incorporating insights from *The Applicability of Commercial Supply Chain Models in Humanitarian Supply Chain Thinking* [9], of Duddy, and *The Triple-A Supply Chain* [17], of Lee, to highlight the adaptations required when transferring commercial models into crisis

contexts. This structure allows the reader to progressively engage with both conceptual frameworks and the practical challenges of humanitarian logistics. how they change and function during emergencies caused by natural disasters or conflicts.

This part of the work was based on both practical observations and key academic studies. One of the main references was the model by Kovács and Spens, which breaks down humanitarian logistics into three main phases: preparation, immediate response, and recovery. This model helped organize the analysis by showing how supply chain operations shift depending on the stage of the disaster. It also clarified the different roles played by various organizations at each phase, making it easier to understand who does what, and when.

In addition to this, the thesis explored whether traditional commercial supply chain models could be applied to humanitarian settings. The study by Duddy was particularly useful for this purpose. It pointed out that many commercial models assume a stable and predictable environment, which doesn't match the reality of humanitarian operations that are often chaotic and unpredictable. Instead, Duddy, suggest thinking of humanitarian supply chains more like flexible networks than rigid chains. They propose a systems-thinking approach as a better way to capture the complexity and interdependencies in humanitarian operations.

The work also considered Triple-A supply chain model, which emphasizes agility, adaptability, and alignment as core elements of effective supply chains. Although originally developed for commercial contexts, these principles provided a useful lens for assessing the capacity of humanitarian supply chains to respond to unpredictable and rapidly changing environments. The emphasis on alignment was especially relevant for understanding how different humanitarian actors, often with diverging goals and limited coordination, must work together effectively to avoid duplication of efforts and wasted resources.

To make sure the theory matched reality, expert interviews were used to compare what the literature says with what happens in real-life situations. These interviews revealed common challenges such as poor coordination between groups, damaged infrastructure, complex rules, and pressure from donors. These issues supported the need to adapt traditional models and include more realistic views of the conditions faced by humanitarian workers.

By combining academic models and real-world experiences, the analysis created a practical and useful framework for understanding HSCs. The approach used in this part of the thesis was flexible and interactive, allowing theory and practice to influence each other. Special attention was given to understanding the balance between being quick and responsive

(agility) and being responsible and organized (accountability), which is often a difficult trade-off in humanitarian work.

### 3.3. Ranking

After undertaking a comprehensive evaluation of the **HSC**, it is essential to identify the most relevant cases. In recent years, as already mentioned, both the number of armed conflicts and catastrophic natural events have been on the rise, posing significant logistical challenges to the delivery of humanitarian aid. These crises strain existing infrastructure and complicate coordination among government agencies, non-governmental organizations, and local communities.

While this selection does not aim to diminish the gravity of other crises, its purpose is to highlight those events that have significantly impacted the **HSC**, thereby revealing patterns and vulnerabilities pertinent to future interventions. From these investigations, concrete recommendations and best practices will emerge, which will help improve the overall efficiency, flexibility, and resilience in supply chain management, ensuring that critical resources reach affected populations promptly despite complex and constantly evolving operational challenges.

The initial phase of case selection focused on using **IDPs** as a primary driver. This choice was made based on two principles:

1. The presence of many individuals needing assistance increases the case's complexity, making it more interesting from a logistical standpoint.
2. A large volume of displaced persons indicates that if best practices aimed at enhancing the efficiency of the **HSC** are identified, it would be possible to assist a broader population of vulnerable people in the future.

That said, certain issues arise: conflicts and disasters produce different quantities of **IDPs**, thus necessitating a distinction between armed conflicts and natural calamities. These latter generate widely varying volumes of displaced persons and have therefore been categorized as follows:

- Earthquakes
- Floods
- Wildfires
- Volcanic eruptions

Each of these types was then associated with an **IDP** threshold that determines whether the event is included in the list of potentially significant cases:

Event	Earthquakes	Floods	Wildfires	Volcanic Eruptions	Wars
<b>IDPs</b>	>10,000	>1,000,000	>5,000	>30,000	>1,000,000

Table 3.1: Threshold for the first case selection

This approach was adopted to avoid including minimally relevant events for a given event type. The thresholds were selected by rounding the lower bound formula from the Box Plot Mary Eleanor Spear [25]:

$$\text{Lower Bound} = Q_1 - 1.5 \times (Q_3 - Q_1) \quad (3.1)$$

Where:

- $Q_1$  is the first quartile (25<sup>th</sup> percentile),
- $Q_3$  is the third quartile (75<sup>th</sup> percentile),
- $Q_3 - Q_1$  is the interquartile range (IQR).

Additionally, for conflicts—protracted events that often span several years—the highest annual **IDP** figure (between that generated during the year and at year-end) was considered. In contrast, the number of **IDPs** at the end of the year was used for natural disasters.

Following this first selection, an initial list of cases emerged, but it remained too extensive to be examined comprehensively in a single study. Moreover, several individual crises are so distinctive that they warrant dedicated research to investigate their specific logistical and operational dynamics in greater depth.

Hence, further screening became necessary. New variables were introduced to enhance the informational framework and enable an even more rigorous assessment of the implications associated with each selected case. These new variables were also suggested by the NGO operators interviewed:

- **Fatalities:** the death toll is a fundamental indicator of the severity of a disaster. Sector-specific literature highlights that a higher number of victims is often linked to

an event of larger dimensions and complexity, implying a more significant logistical challenge in organizing relief efforts.

- **Logistic Performance Indicator (LPI):** developed by the World Bank, this index measures a country's logistics capabilities, considering infrastructure, customs procedures, service efficiency, and delivery times. This indicator becomes crucial when attempting to correlate the performance of a logistical system with the speed of response in emergencies.
- **Area:** the geographical extent of the disaster, expressed in square kilometers, directly affects transportation costs, the distribution of storage facilities, and the complexity of road or air networks required. Events covering exceptionally vast areas may significantly complicate intervention planning.
- **Number of newspaper articles:** using the ProQuest database, one can extract the number of articles covering the event, filtering by year, country, and type of catastrophe. Extensive media coverage may lead to greater international attention and potentially increased resources for aid.
- **Damage cost:** the monetary value of losses and infrastructure damage, expressed in dollars, provides another measure of the event's economic impact. Moreover, events with large-scale damages often reflect extensive disasters—usually affecting infrastructure—requiring more complex planning and significant response resources.

The primary goal of this information expansion is to create a more comprehensive analytical framework. In doing so, it becomes possible to shape a multi-parameter assessment capable of reflecting the complexity of emergency scenarios. However, the challenge lies in harmonizing and appropriately weighting each data point since the influence of each variable can differ considerably depending on the nature of the disaster and the social, economic, and political context in which it occurs. To overcome this hurdle, it was decided to employ a ranking system using the **Analytic Hierarchy Process (AHP)** [2.1.4]. Each variable is evaluated through expert judgment, and a weight is assigned proportionally to its relevance. The collected data are then transformed into scores and summed according to those weights until a final ranking is defined.

Following a preliminary analysis of the scores, it was deemed appropriate to develop two separate rankings: one for natural disasters and another for armed conflicts. This decision stemmed from the observation that wars have a substantially different nature compared to natural disasters, which are usually of much shorter duration; thus, the approach to the **HSC** differs between the two cases. Moreover, this subdivision made it possible to

fine-tune the weights assigned to conflict-related variables, with particular emphasis on parameters such as the number of fatalities, which is typically more significant in warfare than in natural disasters.

The dual classification also provided an opportunity to highlight the role and significance of natural disasters more effectively, allowing for greater focus on the specific logistical challenges posed by each phenomenon. As for conflicts, the variable related to damage costs was excluded due to the high variability of the sources (approximately 25% of the average value), which could undermine the robustness of the comparison. Removing this variable enables a more homogeneous and coherent analysis centered on parameters of greater relevance to conflict contexts.

Two pairwise comparison matrices were developed within the analysis, and the procedures outlined by Saaty's method were applied. For natural disasters, which included six different reference variables, a Saaty Random Index of 1.24 was used, whereas for armed conflicts involving five variables, a Random Index of 1.12 was adopted. This approach yielded a consistency ratio of 0.066 for the first category and 0.0795 for the second—well below the critical threshold of 0.1—thus indicating high coherence in the evaluators' judgments.

In the subsequent step, the relative weights of the variables were determined by calculating the average of the scores, interpreted as the percentage of each variable's contribution to the final result. However, before proceeding with the weighting, it was necessary to normalize each parameter within a range between 0 and 1 to adjust for any discrepancies related to scale or unit of measurement. This normalization step proved crucial for facilitating a homogeneous comparison across heterogeneous data while eliminating potential distortions.

The resulting formulas from this process are as follows for disasters:

$$\begin{aligned} \text{Score} = & \mu_1 \times \text{Fatalities} + \mu_2 \times \text{Area} + \mu_3 \times \text{Number of Newspaper Articles} \\ & + \mu_4 \times \text{Damage Cost} - \mu_5 \times \text{LPI} \end{aligned} \quad (3.2)$$

And for conflicts:

$$\begin{aligned} \text{Score} = & \theta_1 \times \text{Fatalities} + \theta_2 \times \text{Area} + \theta_3 \times \text{Number of Newspaper Articles} \\ & - \theta_4 \times \text{LPI} \end{aligned} \quad (3.3)$$

Where  $\mu$  and  $\theta$  represent the calculated averages for disasters and conflicts.

Based on these defined weights, overall scores were then computed for the two rankings—one dedicated to natural disasters and the other to armed conflicts—and subsequently normalized within a 0–100 range, thus making the values more accessible to researchers and decision-makers. To further improve the interpretability of the results, the rankings were divided into three tiers following the **MoSCoW** model [34], each with a span of 33%. In this way, it was possible to transparently highlight which cases were a top priority (**Must Have**), which ones could be studied on an optional basis (**Could Have**), and which were not central for immediate analysis (**Won't Have**).

In parallel, an additional parameter was introduced to distinguish those cases with a broad information set from those with more limited available data. In this context, special attention was paid to aspects such as the continuity of the historical data series, the presence of cross-references in international sources, and the reliability of the collected information. This classification serves as a valuable tool for future studies, as it guides researchers toward better-documented scenarios or, where appropriate, highlights areas needing further investigation.

Another aspect that emerged during the evaluation process is the possibility of integrating this methodology with qualitative analyses to capture sociopolitical or structural factors that may elude a purely quantitative assessment. In this regard, Saaty's method retains all its systemic effectiveness, provided it is enriched with interviews, focus groups, or field studies to offer an even more comprehensive picture—although that is not the goal of this text.

### 3.4. Case Studies and Factors Analysis

The case studies presented in the Discussion Chapter form the culmination of the research design and serve a dual purpose: to contextualize theoretical insights and to empirically validate key operational dynamics of HSCs under different types of crises. These case studies were selected through a structured process that combined analytical rigor with practical considerations. The ranking matrix, developed in the earlier phases of the methodology, played a pivotal role in this selection by enabling a systematic evaluation of displacement events based on various weighted criteria such as the total number of IDPs, geographical coverage, crisis typology (natural vs. conflict-induced), and strategic relevance to global humanitarian logistics trends.

However, the numerical outcome of the matrix was not the sole determinant. A decisive criterion for inclusion was the richness and accessibility of information related to each case. Only contexts that provided sufficient depth of data—both qualitative and quanti-

tative—were deemed viable for detailed study. The ability to reconstruct a supply chain response based on institutional reports, operational evaluations, academic literature, and interview insights was essential. This approach ensured analytical depth and cross-case comparability. The selected cases—Nepal, Pakistan, Ukraine, Democratic Republic of the Congo, and the United States—represent a wide spectrum of geographic, economic, and political contexts. This diversity enhances the generalizability of insights and supports the identification of both localized and systemic patterns in humanitarian response.

For each case, the analysis focused on the triggering event, the main humanitarian consequences, the organizations involved in the response (including NGOs, UN agencies, government bodies, and local authorities), and the key components of the supply chain activated. The goal was not merely to document individual events but to build a comparative framework capable of identifying recurring patterns, operational divergences, and their implications for logistics management in emergency contexts.

Specific attention was devoted to several key operational dimensions: the speed of response; inventory management practices, including prepositioning strategies; coordination mechanisms between international and local actors; the logistical accessibility of affected areas; and the efficiency of information flows. The influence of pre-existing infrastructure, the broader political environment, and societal stability was also assessed in determining the logistics strategies adopted. A core focus was placed on the adaptability of operational solutions in relation to the nature of the crisis. While natural disasters tend to demand rapid, large-scale mobilizations, conflict-induced crises typically require sustained, adaptable approaches where issues like access, security, and continuity become paramount.

This multi-dimensional analytical approach aimed not only to examine logistical and technical challenges but also to shed light on the broader strategic and organizational determinants of success. By conducting a comparative reading of cases that differ significantly in nature, scope, and setting, it became possible to build a more comprehensive and nuanced understanding of the factors that shape humanitarian logistics outcomes on a global scale.

To support this analysis, a structured framework of critical factors was developed. These factors emerged from a triangulation of sources: academic literature, expert interviews, and insights drawn directly from the case study analyses. The integration of these perspectives allowed for a balanced and evidence-based identification of key determinants of HSC effectiveness. From the literature, particularly the studies *"Exploring Critical Success Factors (CSFs) of Humanitarian Supply Chain Management (HSCM) in Flood Disaster Management"*[8] and *"The Role of Big Data in Explaining Disaster Resilience in Sup-*

*ply Chains for Sustainability*"[31], a broad range of critical dimensions was established. These included managerial leadership, planning, communication, stakeholder coordination, infrastructure, information flows, and resilience mechanisms such as public-private partnerships and swift trust.

Interview data complemented these findings by highlighting practical constraints and operational enablers encountered by humanitarian actors in the field. Themes such as local capacity, logistics adaptability, funding stability, and security considerations surfaced consistently. Finally, through the comparative study of the five selected cases, these factors were validated and further refined. The diversity of operational environments provided a unique opportunity to assess how these critical factors manifest in practice and influence performance across different contexts.

The synthesis of literature, interviews, and case-based evidence resulted in a robust and actionable framework. This served as the analytical backbone of the Discussion Chapter, guiding the identification of systemic vulnerabilities, success conditions, and transferable best practices. The multi-source methodological approach reinforces both the depth and applicability of the findings, offering a sound foundation for academic advancement and strategic decision-making in humanitarian logistics.

The development of the critical factor's framework was integral to the interpretation of the case studies. These factors were not arbitrarily selected but emerged from a robust triangulation process. The first layer of input came from a series of semi-structured interviews with humanitarian logistics practitioners and case studies. These insight highlighted core operational priorities and revealed patterns of success and failure in real-world responses. Factors such as coordination, logistics adaptability, infrastructure reliability, funding mechanisms, and workforce readiness were frequently mentioned as essential determinants of operational effectiveness.

To strengthen the empirical validity and broaden the theoretical foundation, two peer-reviewed academic studies were incorporated. The first, "*Exploring Critical Success Factors (CSFs) of Humanitarian Supply Chain Management (HSCM) in Flood Disaster Management*"[8], offered a statistical validation of critical factors based on a Ghanaian flood response context. It identified a comprehensive set of internal and external variables such as management quality, training and education, stakeholder collaboration, infrastructure adequacy, and resource availability that significantly influence HSC success. These dimensions align with broader logistical theory and are applicable across disaster types.

The second reference study, "*The Role of Big Data in Explaining Disaster Resilience in Supply Chains for Sustainability*"[31], brought a complementary perspective focused on

system resilience. Based on data from the Nepal earthquake response, this study emphasized the role of swift trust, effective public-private partnerships, and high-quality information sharing as enablers of supply chain resilience and sustainability. These insights broadened the scope of analysis beyond operational efficiency to include system adaptability and long-term robustness.

### 3.5. Factors Ranking

An additional phase of research was conducted using the Delphi method to further refine the framework of critical factors and evaluate their perceived importance within the humanitarian logistics domain. This method allowed the research team to capture a structured consensus among experts and enhance the analytical robustness of the factor framework. Engaging the same professionals who had previously contributed during the interview phase ensured continuity and drew upon a depth of experiential knowledge accumulated over diverse contexts and crises. This ranking effort's primary aim was to validate each identified factor's relevance and prioritize them based on their strategic and operational significance in humanitarian supply chain management.

The Delphi technique is a structured, iterative process designed to obtain a reliable consensus from a panel of subject-matter experts through multiple rounds of questionnaires, each followed by controlled feedback. This research implemented a two-round Delphi process to establish an ordered hierarchy of the critical success factors in humanitarian logistics. This method was selected for its flexibility, anonymity of responses, and ability to promote convergence without confrontation or group pressure.

During the first round (appendix A.2), a comprehensive survey was distributed to all participants previously involved in the qualitative interviews. The survey contained the complete list of critical factors identified from the triangulation of literature review, field interviews, and case study examination. Each factor was accompanied by a concise yet informative definition based on existing academic and operational sources to ensure a consistent and shared understanding. Respondents were asked to score the importance of each factor on a scale from 1 (not important) to 10 (extremely important). Additionally, each item included a free-text comment section where respondents could elaborate on their scoring rationale, provide real-life examples, or express concerns regarding relevance, scope, or clarity. These qualitative remarks added substantial depth and nuance to the dataset, capturing subtle distinctions that numeric scores alone might obscure.

After collecting the first-round responses, the data were processed to identify central tendencies and divergences. Average scores for each factor were computed, and the qualitative

comments underwent thematic analysis using coding techniques to highlight converging opinions, points of contention, and emergent insights. This synthesis was used to generate concise comment summaries for each factor that reflected the range of expert feedback.

Participants received an updated version of the same survey in the second round. This revised survey included each factor's average score from round one and the accompanying thematic summary of participant feedback. The intent was to inform and provoke thoughtful reconsideration rather than drive forced agreement. By reviewing their peers' collective perspective and rationale, respondents had the opportunity to reassess and, if desired, revise their original ratings in light of new insights. This structured feedback loop enabled a richer and more considered judgment, often leading to a tighter convergence of opinions on contentious or ambiguous factors.

The guiding principle behind this iterative approach was not to impose artificial consensus but to facilitate reflective, evidence-informed alignment. By encouraging participants to engage with the perspectives of others, the process supported a more nuanced and democratic prioritization of the factors under evaluation.

The Delphi study resulted in a ranked list of critical factors, each accompanied by its final average score and supported by qualitative rationale. This ranked output provides a prioritized roadmap for practitioners and a deeper understanding of why certain factors are consistently valued across diverse operational settings. Factors such as stakeholder coordination, logistics adaptability, and infrastructure readiness emerged as consistently top-rated, while others showed more variability depending on the expert's background or regional focus.

This final ranking played an integral role in shaping the subsequent analysis presented in the Results Chapter. It served as a validated framework for interpreting real-world HSC performance and guiding the design of targeted interventions. Moreover, the consensus-driven output allowed for the identification of universally agreed-upon priorities and areas where perceptions diverged—critical insights for tailoring recommendations to specific stakeholder needs or regional contexts.

Importantly, this information was combined with the best practices associated with each critical factor. These best practices, drawn from a combination of field documentation, operational guidelines, and practitioner literature, enabled the formulation of concrete recommendations. They provided actionable guidance for improving supply chain resilience, coordination, resource allocation, and operational efficiency in humanitarian settings. The resulting framework supports strategic planning and practical implementation across varied humanitarian contexts by linking expert consensus with applied knowledge.

# 4 | Discussion

Many NGO were invited to collaborate to our research from an initial list of over forty organizations, nine consented to engage in our research. The following organizations were the one who agree to participate to our research:

1. **World Food Programme (WFP)**
2. **International Red Cross and Red Crescent (IRC)**—This includes the **International Committee of the Red Cross (ICRC)** and the **International Federation of Red Cross and Red Crescent (IFRC)**, with the former focusing on natural disasters and the latter on armed conflicts.
3. **Oxfam (OX)**
4. **Médecins Sans Frontières (MSF)**
5. **Logistics Cluster (LC)**
6. **Direct Relief (DR)**
7. **Action Aid (AA)**
8. **Emergency (EE)**

## 4.1. HSC Analysis

By synthesizing the insights from experts and the wealth of knowledge in academic papers, we can construct a comprehensive view of the current state of the HSC. This approach, which encompasses the primary procedures and mechanisms, ensures a thorough understanding of the subject under examination.

### 4.1.1. Humanitarian Supply Chain Evolution

Over time, the definition of classical HSC has broadened into HSCM, reflecting the realization that its scope extends beyond transportation and inventory management. Rather

than simply moving food or medicine into a disaster zone, HSCM now encompasses:

- Coordinated the planning of procurement,
- Partnerships with suppliers and manufacturers,
- Inventory pre-positioning in strategic hubs,
- Real-time data visibility of shipments,
- Distribution to beneficiaries,
- Reverse logistics (e.g., disposal of unwanted donations),
- Performance management is conducted through metrics such as lead times, cost efficiency, and fill rates for critical goods and services.

Major organizations, including the IRC, the WFP, and various NGOs, have taken significant steps to formalize HSCM frameworks. These efforts, which involve the development of standardized processes for needs assessment, sourcing, warehousing, last-mile distribution, and performance feedback, serve as a testament to the field's progress and the commitment of these organizations to enhancing humanitarian logistics and supply chain management.

Historically, humanitarian operations were often run with minimal formal processes and sometimes lacked technical tools. Many agencies had small administrative structures or relied on volunteers, local staff, and ad hoc decision-making to meet urgent needs. Over time, as large-scale disasters became more frequent—both because of actual disaster occurrences and the global media coverage that amplified awareness—relief organizations realized that effective logistics was not merely a back-office function. Instead, logistics could be a significant determinant of the speed and impact of relief.

#### 4.1.2. Collaboration Model

The analysis of the data from the questionnaires shows that cooperation between NGOs, governments, local authorities and private actors is a fundamental pillar for the effectiveness of rescue operations. In particular, small NGOs, which often face budget and staffing constraints, can benefit greatly from the expertise and transport networks provided by larger organisations. This synergistic approach avoids duplication, maximises the use of available resources and improves the impact of aid, especially in situations where rapid response is essential to contain damage. The paper "*The Applicability Of Commercial SC Models In HSC Relief Operations*" [9] emphasizes that the adoption of classic supply chain models, such as SCOR, is only beneficial when accompanied by constant information

sharing practices and a flexible governance structure. The humanitarian context, in fact, makes the presence of agile collaboration networks crucial, capable of reacting promptly to the sudden changes in the scenario typical of crises. Regional and global partnerships often emerge, such as the Logistics Cluster (LC), led by the WFP, which coordinates shipments from multiple NGOs onto the same cargo planes or helps establish shared storage facilities in disaster zones. The goal is to pool resources, reduce duplication, and enable agencies to leverage each other's capabilities. Yet, forming and sustaining these collaborative supply networks can be challenging. Agencies compete for donor attention, have different organizational mandates, or rely on staff with varying professional experience. Moreover, differences in technology platforms and data standards hinder the integration of information flows. In this sense, the concept of "network orchestrators" can facilitate the coordination of the overall HSC, with one lead actor assuming responsibility for aligning processes, ensuring transparency, and enforcing specific communication or data-sharing standards.

Over the past decade, new forms of collaboration have emerged among humanitarian organizations to address persistent coordination gaps. Some notable examples include:

- **Consortia or Alliances:** Groups of agencies sign agreements to jointly implement programs, share overhead costs (like warehousing), and submit consolidated funding proposals. This can streamline logistics but also requires high levels of trust.
- **Pooled Funds:** Under these arrangements, donors pool money into a common fund managed by a central body (often administered by the UN), which then disburses grants to agencies based on assessed needs. This can reduce competition among agencies and provide a more equitable distribution of resources.
- **Shared Services Initiatives:** Agencies collaborate on services, such as joint procurement of relief items to secure bulk discounts or share cargo space on chartered flights. The Logistics Cluster is a prime example of this principle in action.
- **Public-Private Partnerships:** Partnerships with global logistics firms, technology companies, or manufacturers can boost efficiency and innovation in relief supply chains. When well-structured, such collaborations reduce duplication, leverage private sector expertise, and speed up the flow of goods.

In many humanitarian crises, the private sector also steps in, driven partly by corporate social responsibility (CSR) goals and partly by recognizing that functioning communities and stable markets serve long-term commercial interests. Examples include logistics firms like DHL or UPS offering pro bono air transport or warehousing services to humanitarian

agencies in the aftermath of disasters, such as in the case of LC. Partnerships may also arise with technology giants that donate information systems or manufacturers reconfiguring production lines to produce relief items. This synergy can bolster the resilience and capacity of humanitarian supply chains, bringing specialized expertise and resources at critical moments. These public-private partnerships require deliberate planning so that corporate involvement does not merely become a short-lived public relations effort but leads to a meaningful and sustained impact. Aligning corporate timelines, which are often oriented toward quarterly results, with the humanitarian context, which frequently demands months or years of investment, is challenging. However, successful cases demonstrate that when private partners are given a clear operational role and remain committed beyond the initial response, humanitarian supply chains can be strengthened through the infusion of commercial best practices.

### 4.1.3. Phases of HSC

The phases of the HSC, intricately linked to the concept of disaster management, can be categorized into four stages: preparedness, response, recovery, and mitigation. This categorization, supported by various resources, highlights the importance of understanding the evolving nature of supply chain priorities and challenges over time. While these phases may overlap, viewing them as distinct stages provides a structured approach to understanding the dynamic nature of the field and the evolving challenges it presents.

Humanitarian logistics are involved in all phases of the disaster management cycle, encompassing preparedness, immediate response, recovery, and mitigation. The “preparedness” phase involves stocking pre-positioned inventory in strategic locations, developing strong coordination channels among agencies, and creating contingency plans. “Immediate response,” which typically begins in the first hours to days following a disaster, is where rapid mobilization of supplies and resources is critical to prevent further loss of life. The “recovery” phase encompasses a longer timeframe, supporting communities transitioning from emergency relief to restoring their infrastructure and livelihoods. Ultimately, “mitigation” seeks to reduce vulnerabilities and prevent or mitigate the impact of future disasters.

Logistics and supply chain requirements differ in each phase. Preparedness may emphasize robust forecasting and pre-positioning of inventory. The immediate response phase focuses on rapid transport, last-mile distribution, and ad hoc problem-solving. Recovery efforts require longer-term planning, cooperation with local institutions, and, in many cases, more stable supply routes. Thus, the end-to-end humanitarian supply chain must adapt

fluidly to distinct goals throughout the cycle, which revolve around meeting beneficiaries' needs in timely, efficient, and ethically and culturally sensitive ways.

Modifying the Resilience Core Function Model [3] can also illustrate these four phases. On the y-axis, rather than indicating the performance level, we can represent the “Disaster Entity,” a percentage ratio of the actual damage relative to the maximum damage a disaster can inflict. In this example, we show an earthquake.

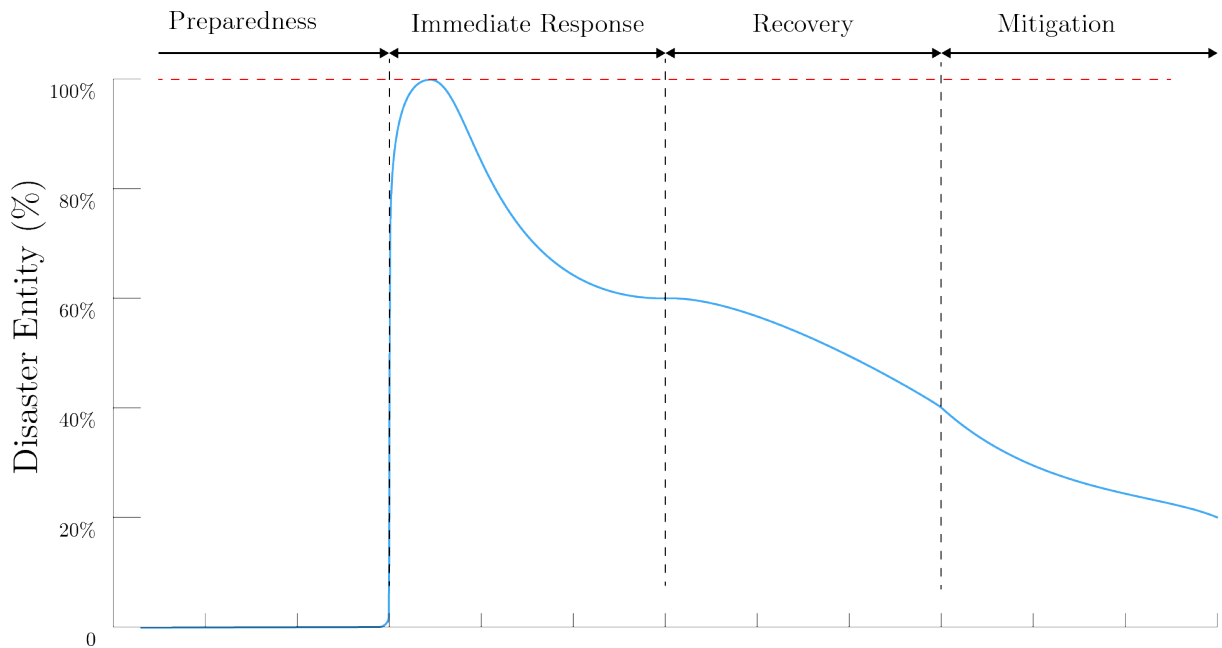


Figure 4.1: Resilience Core Function Models

### 1. Preparedness Phase

- **Risk Analysis and Forecasting:** Humanitarian organizations identify high-risk regions and potential threats using data on weather patterns, historical events, and vulnerability assessments.
- **Pre-positioning of Goods:** Agencies often store emergency relief items, such as tents, medical kits, blankets, and water purification units, in strategic warehouses near disaster-prone regions.
- **Partnerships and Training:** Humanitarian logisticians collaborate with local governments, commercial transporters, and community-based organizations to clarify roles and responsibilities.
- **Coordination Mechanisms:** Many organizations sign memoranda of understanding with each other or form clusters to facilitate rapid mobilization.

## 2. Immediate Response Phase

- **Rapid Deployment of Relief:** When a disaster strikes, humanitarian actors activate their plans to deploy emergency teams, supplies, and equipment. Speed is critical to prevent further loss of life and suffering.
- **Transportation and Distribution Challenges:** Damaged infrastructure complicates the movement of supplies. Organizations may rely on air cargo drops, sea, or ad hoc road routes.
- **On-the-Ground Coordination:** Agencies establish emergency operations centers or utilize cluster-based approaches to streamline information sharing, including the location of distribution sites and prioritized needs.
- **Scaling Up or Down:** The volume of relief materials can rise sharply within days of an event. For example, in a large-scale earthquake, thousands of tons of relief cargo may flood airports, creating congestion and backlogs.

## 3. Recovery Phase

- **Transition from Relief to Rehabilitation:** Supply chain processes shift from the urgency of life-saving interventions to supporting medium-term needs, including rebuilding homes, restoring livelihoods, and re-establishing local markets.
- **Focus on Local Procurement:** Wherever feasible, agencies should source rebuilding materials and goods from local or regional suppliers to stimulate the local economy, reduce lead times, and lower transportation costs.
- **Longer-Term Infrastructure Projects:** Partners collaborate with local authorities to restore roads, bridges, and other critical logistics enablers. The supply chain has evolved to handle bulk construction materials and specialized equipment.
- **Scaling Back External Actors:** As local capacity improves, global agencies often wind down direct service provision and hand over responsibilities to local or national entities. An example of this can be the USAID situation.

## 4. Mitigation Phase

- **Investing in Risk Reduction:** Ideally, stakeholders incorporate lessons learned from the previous phases to reinforce infrastructure, improve building codes, or enhance early warning systems.

- **Strengthening Community Resilience:** Long-term investment in community-led approaches—such as training local relief committees, establishing micro-insurance programs, or developing livelihood diversification—can mitigate future vulnerability.
- **Monitoring and Evaluation:** Evidence-based studies and after-action reviews inform the development of improved disaster preparedness strategies.

#### 4.1.4. Type of NGOs

Humanitarian supply chain operations vary greatly depending on the type of disaster or crisis at hand. Disasters are broadly categorized into natural and artificial categories, although many crises share overlapping features. Natural disasters include earthquakes, hurricanes, floods, tsunamis, droughts, and volcanic eruptions. Artificial disasters involve armed conflicts, technological accidents (e.g., nuclear meltdowns), industrial hazards (e.g., chemical spills), or terrorist attacks. Some protracted crises, such as prolonged civil conflicts, may blend characteristics of both.

Each disaster type presents distinct challenges for humanitarian supply chains:

1. **Sudden-Onset vs. Slow-Onset Disasters:** Sudden-onset events (e.g., earthquakes) yield immediate, unpredictable spikes in demand for relief goods and can severely damage infrastructure. Slow-onset events (e.g., droughts) develop gradually, allowing for earlier detection and longer lead times. While slow-onset crises might seem easier to manage, they can strain resources over time, especially if donors or the media lose interest.
2. **Complex Environment:** Multiple simultaneous threats—such as violence, political unrest, and displacement—complicate logistics and operations. Examples include civil wars, famine, or an epidemic outbreak amid ongoing conflict. Coordination and security become paramount in these scenarios, as supply lines may need armed escorts or rely on secure air corridors.
3. **Technological:** In accidents such as major industrial facility explosions, nuclear power plant failures, or large-scale chemical spills, humanitarian organizations often collaborate with government agencies and specialized teams. This requires specialized logistics capabilities, including transporting protective equipment and establishing quarantine or decontamination stations.

By recognizing the type of disaster and its context, humanitarian organizations can anticipate specific supply chain needs. For example, large-scale flooding may require boats

or amphibious vehicles for last-mile delivery, while armed conflict might necessitate security coordination with military units. As a result, agencies often develop scenario-specific contingency plans and pre-position certain goods or assets.

A further important aspect, which emerged during the analysis, concerns the classification of NGOs according to size, resources and scope of intervention. Large international organizations (think, for example, of WFP or DR) have substantial financial and logistical resources, often supported by rigorous and standardized procedures, as well as by the presence of warehouses already located in strategic areas. Medium-sized NGOs, on the other hand, are oriented towards a specific sector (e.g. health or education) or a limited geographical context, while relying on external sources of funding and collaborations with national governments or regional authorities. Finally, small NGOs, or grassroots associations, focus on small communities and, despite limited budgets, ensure an agile and targeted response thanks to in-depth knowledge of the territory and local needs. These differences are directly reflected in the organisational structure: larger companies tend to favour hierarchical structures, while smaller ones often show greater flexibility and a more horizontal approach to decision-making.

The first difference is in their structural approaches to governance. Some adopt a centralized model, where headquarters makes decisions on procurement, inventory levels, and distribution strategies and then directs field offices to implement them. Others take a decentralized approach, giving significant autonomy to regional or national offices, which can adapt their supply chain strategies to local conditions.

### **Centralized Model:**

A type of organization where the entire supply chain is managed by a centralized office, with smaller offices in other countries better to handle the final stages of the supply chain.

- Advantages: Standardization of procedures, economies of scale in procurement, clear lines of authority, and easier global coordination.
- Disadvantages: A slower response if the headquarters is far removed from the disaster zone, limited flexibility, and potentially lower buy-in from local partners.

In this category, we have NGOs such as Emergency, WFP, LC, DR, and MSF, some of which have additional offices worldwide. However, the primary decision and verification regarding the start or continuation of operations is made by a central headquarters.

Taking the example of MSF, when a disaster occurs, the team begins assessing the situation on-site, evaluating the disaster's impact, determining if a squad is already present in that country, and verifying whether the government has the necessary capabilities and

tools to respond. All this information is considered and sent to a review team in Brussels, which determines whether to act and the required level of effort.

#### **Decentralized Model:**

Each regional or country office determines its own operations and supply chain management, but a central office controls and coordinates all smaller offices as needed.

- **Advantages:** Quicker decisions are closer to the point of demand, there is higher adaptability to local contexts, and local ownership is fostered.
- **Disadvantages:** There is a risk of inconsistencies, duplication of efforts across field offices, and difficulty achieving cross-country coordination or knowledge sharing.

This type of governance is employed by organizations such as the IRC and AA, which have various regional offices that make decisions for their respective areas of competence, primarily countries. When necessary, they seek assistance from headquarters, which coordinates with other offices to provide the required materials and personnel.

To better understand this typology, it is helpful to analyze how the IRC functions. They have various country groups that activate when a disruption occurs. If this group can manage the disruption, it operates like an independent organization. If it lacks the means to handle the situation, it can seek assistance from the ICRC for non-conflict events or from the IFRC for conflict-related events to receive aid from other country groups.

There is another critical difference in how various NGOs structure their approach to providing humanitarian assistance during an operation. The interview revealed three primary ways to deliver the necessary aid:

**Direct Structure Only:** This type of NGO typically has a central warehouse or a few warehouses in strategic areas. When they arrive at the disaster area, they establish a camp hospital or a distribution center for aid materials to the population, utilizing minimal warehouse space; the materials are stored directly at the camps. In this category, there are organizations like Emergency.

**Complex Supply Chain:** These NGOs establish a complex supply chain to support their target populations. When they arrive at the designated area, they have already prepared a plan to create warehouses on multiple levels, ensuring materials' resilient and timely delivery. In this scenario, the most prominent NGOs operating worldwide, such as MSF, WFP, and AA, are involved.

**Supply and Coordination Support:** This type of NGO is either the smallest or part of a larger organization. This organization provides coordination support, meaning it

organizes all the NGOs operating in the area or supplies materials to send to those NGOs in the region. None of these NGOs maintain warehouses or camps in the country where the disaster occurs, but they have warehouses in strategic locations worldwide. In this category, NGOs like LC for coordination and DR send materials from their warehouses in the USA.

#### 4.1.5. HSC Common Stakeholders

It is also essential to consider the plurality of stakeholders operating within the HSC, whose roles can be complementary or sometimes overlapping. In addition to NGOs, governments play a decisive role, responsible for authorizations and political choices; military and peacekeeping forces, which ensure the security of humanitarian corridors; donors and sponsors, who are increasingly demanding transparency and specific reporting on the funds disbursed; and local communities, valuable sources of information and manpower. Private providers, on the other hand, have the task of providing transport, technology, infrastructure and support services that are essential for the effective distribution of aid. Investigations show that mutual trust between these actors, fueled by constant and transparent communication, is a key factor for the success of the humanitarian mission: overly complex bureaucratic procedures or lack of clarity can in fact dramatically slow down the arrival of aid, to the detriment of the timeliness of operations:

- **International NGOs:** Often large and well-funded, they bring global reach, technical expertise, and specialized programs. They may send teams from abroad to manage response efforts. Their role also includes partnering with local actors to scale up interventions. For example, LC, which we discussed earlier, offers its organization to other NGOs.
- **Local NGOs and Community-Based Organizations (CBOs):** These entities possess intimate knowledge of the local area, culture, language, and power structures. They can access remote communities more efficiently and tailor interventions to local needs. However, they might lack the technical capacity or robust funding that large international NGOs possess.
- **Government Agencies (Local and National):** Depending on the context, governments may lead the entire response operation or be limited in capacity. Ideally, the government's role is to facilitate regulatory approvals, ensure security, and provide strategic oversight. Government authorities coordinate the emergency response in stable contexts, working with national and international actors.
- **Donors (Institutional and Individual):** Official donors (e.g., governments and

large philanthropic foundations) often set conditions on how funds are used, shaping the types of interventions. Individual donors frequently provide in-kind donations, which can be beneficial if they meet actual needs; however, they can also cause logistical strain if the donations are inappropriate or arrive unplanned.

- **Military Forces:** In specific high-security environments or where heavy-lift capacity is required (e.g., large cargo aircraft or helicopters), the military may significantly transport relief supplies. Their engagement can raise questions about neutrality and impartiality; therefore, organizations must establish clear guidelines for using “last resort” military force.
- **Private Sector:** Companies can offer expertise in supply chain technology, data analytics, logistics services, or financing. They may provide pro bono assistance under corporate social responsibility (CSR) initiatives or become contracted vendors. This is very important because many NGOs request help from private warehouse owners to stock materials during their operations.

These actors have unique incentives, accountability mechanisms, and governance structures. While bridging them in a unified effort remains challenging, collaborative approaches can generate comprehensive, well-informed solutions that leverage each stakeholder’s strengths.

#### 4.1.6. From Supply Chain Management to Humanitarian Supply Chain Management

To tackle these complexity, even though it may be difficult to achieve, there is potential in leveraging the model developed for the commercial supply chain. Similar to SCOR Models, Balanced Scorecards, and Maturity Models, this can be accomplished by modifying the models to adapt them to the new context of humanitarian supply chains, which share many traits with the original supply chains. For instance, one could begin with a Lee Matrix fig. 4.2, considering the market’s characteristics, demand, and supply, and then determine the type of supply chain.

While it is tempting to assume that “supply chain management is supply chain management” everywhere, the humanitarian context modifies fundamental assumptions about stability, funding, consumer choice, and competition. Companies typically forecast demand using sales history, competitor analysis, or market research in commercial supply chains. Demand in humanitarian operations depends on the severity and location of sudden disasters, population displacement, or disease outbreak. Similarly, commercial supply

chains are financed by investor capital and operating revenues, whereas humanitarian supply chains rely heavily on donations that can be unpredictable or earmarked.

Additionally, many humanitarian organizations rely on volunteer labor and staff who rotate frequently, resulting in high turnover that hinders institutional memory and continuity. Staff turnover is usually lower in commercial settings, and supply chain knowledge can accumulate within organizations. Finally, the beneficiary’s role—not a paying “customer” in the usual sense—also sets humanitarian supply chains apart from commercial ones. Organizations must serve individuals in dire situations without the typical price signals or brand differentiation that might help shape demand or manage inventory.

It is worth noting that within the broader supply chain discourse, “lean” approaches aim to minimize waste, reduce costs, and maximize efficiency. In contrast, “agile” approaches emphasize responsiveness, flexibility, and the ability to handle significant variations in demand. In practice, many organizations blend these two paradigms into an “agile” strategy that leverages lean when predictability is high and agile when demand is variable. Humanitarian organizations can also benefit from applying lean principles during more stable phases, such as preparedness or routine replenishment, and agile principles during unpredictable phases, like the immediate aftermath of a disaster. This thesis will focus on the agile aspect, as it is critical, with rapid and efficient decisions leading to a more significant number of lives saved.

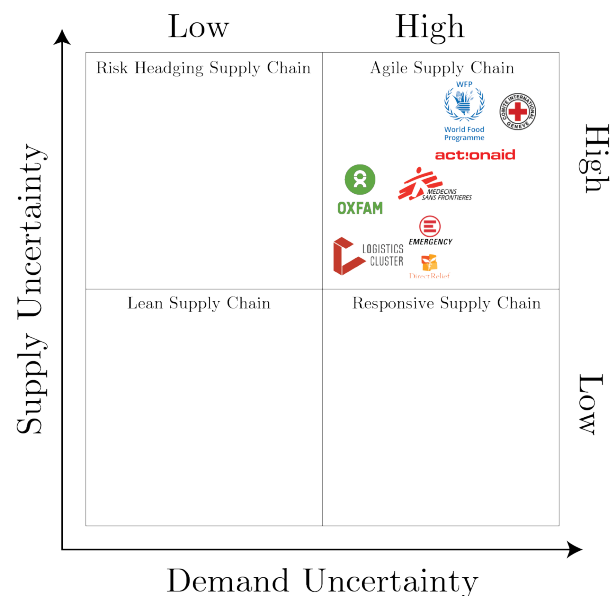


Figure 4.2: NGOs Lee Matrix

As was predictable, the result is that the best model for a humanitarian supply chain is

Agile due to the high uncertainty in supply and demand, as was also evidenced in the previous sections. Although not surprising, this result offers the opportunity to introduce another model from Lee. The "*Triple-A Supply Chain*" [17] notion is often invoked to capture three essential characteristics—agility, adaptability, and alignment—that enable companies to respond effectively to various market challenges. Over the past decade, humanitarian scholars have examined whether these concepts can be applied to humanitarian operations, albeit with some modifications.

1. **Agility:** In a disaster environment, demand can spike without warning, supply routes can be destroyed, and local partners may be overwhelmed or displaced. Agility refers to a humanitarian supply chain's ability to mobilize resources and respond rapidly to unexpected changes. For instance, if a significant earthquake strikes a region, agile humanitarian agencies can quickly divert pre-positioned goods from other locations or organize airlifts. This requires flexible logistics plans, close collaboration with transportation providers, and real-time visibility of inventory data. In humanitarian contexts, agility is further challenged by political barriers, flight permissions, or customs regulations that can delay shipments.
2. **Adaptability:** While agility focuses on short-term responsiveness, adaptability ensures that the supply chain evolves in response to long-term shifts. Adaptability may involve reconfiguring facilities in commercial supply chains as new consumer markets emerge. In humanitarian operations, adaptability might involve establishing permanent regional warehouses in disaster-prone areas, training local staff to handle logistics tasks, or forging long-term partnerships with community-based organizations. These actions enable humanitarian agencies to transition from one-off responses to a sustained capacity for managing recurring or protracted crises, such as long-term refugee situations.
3. **Alignment:** In the commercial context, alignment aims to ensure that all supply chain partners—suppliers, manufacturers, distributors, and retailers—share common incentives, thereby preventing local decisions from undermining overall chain performance. In humanitarian supply chains, alignment is arguably more challenging due to the multitude of different actors—NGOs, donors, governments, and local communities—all with distinct organizational cultures, objectives, and constraints. For example, donors often have strict guidelines on spending money, which may not align well with local preferences or the operational realities agencies face. Achieving alignment in HSCs thus requires transparent communication, clearly agreed-upon objectives, flexible funding mechanisms, and the establishment of inter-agency coordination bodies.

Adapting the triple-A framework to humanitarian settings involves balancing speed, cost, and alignment with humanitarian imperatives, such as impartiality and neutrality, while collaborating with diverse stakeholders across multiple phases of a crisis. For example, an organization that excels at rapid response but struggles to collaborate with local partners will face chronic alignment issues that hinder overall effectiveness.

Overall, the transition from the traditional supply chain to that of the HSC implies a paradigm shift, where efficiency partly gives way to criteria of effectiveness in saving lives and ensuring rapid support for those most in need. Careful planning, strong coordination between the different stakeholders and the adoption of flexible management approaches are essential factors to promptly address the challenges that emerge in different crisis contexts. The following sections will focus specifically on some operational proposals and recommendations for the improvement of emergency management, integrating the results that emerged from this analysis with the main theoretical orientations and experimental evidence provided by NGOs, with the aim of outlining a strategy capable of combining local needs and available resources in the best possible way. always in the name of the speed, effectiveness and humanity of the intervention.

Feature	Organization & Funding	SC Hierarchy & Structure	Emergency Protocol & Response Time	Collaboration Strategy	SC Strategy (Push/Pull, Lee Matrix)	Warehouse Strategy
World Food Programme	UN agency; funded by voluntary contributions from governments, corporate donors, and individuals.	HQ in Rome → Regional Bureaux → Country Offices. Centralized coordination with field execution.	Follows UN protocols; rapid deployment from UNHRD hubs; responses often within 72 hours.	Leads Logistics Cluster; collaborates with governments, NGOs, private sector.	Push-Pull hybrid; agile in emergencies, lean in stable settings.	Regional hubs and local warehouses; hundreds globally; preference for forward deployment.
ActionAid	International NGO federation; mix of public fundraising and institutional grants.	Decentralized; local teams manage logistics, with surge support from international team.	Phase-based response; deployment in 24-48h; kits dispatched as needed.	Coordinates with local NGOs, Start Network, community-based organizations.	Push or Pull depending on context; agile response model during crises.	No permanent hubs; relies on partner or temporary warehouses.
Emergency	Independent NGO; funded by private donations and charitable contributions.	Centralized; HQ in Milan oversees logistics; each project site has a dedicated logistician.	Assessment and tailored team deployment; usually responds within 72h.	Coordinates with local health authorities; avoids cluster system to maintain neutrality.	Lean in stable ops; agile in emergencies; push supplies for trauma response.	Central HQ storage and project site warehouses; separated for medical/non-medical.
Logistics Cluster	Led by WFP; donor-funded; serves coordination role, not direct implementation.	Flat structure; HQ + deployable teams; facilitates partners' logistics.	Activates in major crises; SOPs followed; operates within 24-72h post-activation.	Coordinates UN/NGOs; organizes shared warehousing/transport; partner-driven.	Demand-driven (pull); agile response; facilitates push when required.	Temporary shared warehouses; partner-owned inventory; mobile storage units.
Oxfam	Confederation model; funds from public, charity shops, and institutional donors.	Hybrid model; central supply unit + decentralized execution.	Categorized responses; GHT deploys in 24-72h; pre-packed kits used.	Participates in clusters; shared logistics with partners; field-level engagement.	Push-Pull mix; kits pushed early, then replenished via pull.	UK supply center; local/temporary storage as needed.
Médecins Sans Frontières	Privately funded (~95%); ensures operational independence.	Decentralized among operational centers; strong supply units support field.	Assessment teams deploy in 1-3 days; kits used for fast response.	Coordinates with clusters when needed; generally independent operations.	Routine = pull; emergency = push (pre-packed medical kits).	Global warehouses (Brussels, Bordeaux, Dubai); field-level stores in mission areas.

(Continued on next page)

Feature	Organization & Funding	SC Hierarchy & Structure	Emergency Protocol & Response Time	Collaboration Strategy	SC Strategy (Push/Pull, Lee Matrix)	Warehouse Strategy
Direct Relief	Private donations and in-kind support; no government funding.	Centralized; operates from US HQ warehouse (Santa Barbara).	Rapid shipping (24–48h) from pre-packed inventory; partners initiate requests.	Supplies partner NGOs and clinics; collaborates with logistics firms (e.g. FedEx).	Pull-based with pre-positioned push during known emergencies.	Main hub in Santa Barbara; no overseas depots; uses partner storage abroad.
ICRC	Funded by states party to Geneva Conventions, National Societies, and private donors.	HQ in Geneva; Logistics Support Centers in Kenya, Jordan, Côte d'Ivoire; supported by field delegations.	Rapid deployment units within 48–72h; leverages in-country presence.	Coordinates within Red Cross Movement; avoids formal UN cluster participation.	Push for rapid needs; Pull for ongoing ops; agile during crises, lean otherwise.	Strategic stockpiles at global/regional level; sets up temporary field warehouses.
IFRC	Funded by National Societies, voluntary donations, and institutional donors.	HQ Geneva; regional hubs (Dubai, Panama, Kuala Lumpur); local ops via National Societies.	ERUs and FACT teams deploy within 24–72h; hubs support rapid dispatch.	Global Shelter Cluster co-lead; coordinates across Red Cross network and with external partners.	Push from hubs for immediate relief; Pull after assessment; agile and lean tailored mix.	Main warehouses at 3 hubs; sub-regional prepositioning; scalable field setups.

Table 4.1: Comparison of Humanitarian Supply Chain Organization Structures - Part 1

Feature	Inventory Policy	Transportation Modes	Last-Mile Strategy	KPIs & Tracking	Risk Management Approach	Sustainability Focus
World Food Programme	FEFO/FIFO; real-time tracking; safety stock maintained for core items.	Sea, air, road, intermodal; extensive transport fleet and flexibility.	Direct or via partners; innovative solutions for inaccessible areas.	Tracks delivery times, cost per ton, and distribution accuracy; dashboards in use.	Scenario planning, security protocols, diversified routing and suppliers.	Aligns with UN sustainability goals; green logistics initiatives ongoing.
ActionAid	FIFO/LIFO/FEFO; uses safety stocks where applicable; low inventory profile.	Air and road; intermodal via coordination; local sourcing prioritized.	Community-based delivery; empowered local volunteers manage last mile.	Tracks procurement, spending vs delivery; emphasizes community feedback.	Risk assessed through field teams; flexible funding for rapid mobilization.	Emphasizes resilience, local empowerment, and sustainable recovery practices.
Emergency	FEFO for meds; lean stockholding; buffer maintained for critical items.	Air and sea from HQ; land transport in-country; project-focused logistics.	Delivers to its facilities; outreach when patients can't access hospitals.	Internal KPIs track delivery lead time, stock-outs; logistics cost analysis.	High-risk zones; secure convoys, multiple suppliers, buffer inventory.	Focus on lasting healthcare infrastructure; minimal eco-focus beyond compliance.
Logistics Cluster	No central inventory; relies on partners' FIFO/FEFO policies.	All transport modes based on partner needs; intermodal options supported.	Supports partners for last mile; coordination role only.	Tracks cargo volumes, partner support, response time via RITA, SRF systems.	Prepares for bottlenecks, offers access/security coordination in high-risk areas.	Promotes efficient, coordinated logistics; supports green best practices.
Oxfam	FIFO; kit-based stock levels; contingency stocks sometimes prepositioned.	Road, air, some sea; practical and situation-based use of modes.	Delivered by Oxfam or via trusted local partner organizations.	Procurement lead times, stock levels, reach metrics tracked internally.	Identifies risks, uses mitigation plans, relies on partner flexibility.	Green logistics policy; local procurement, reusable kits, efficiency focus.
Médecins Sans Frontières	FEFO for medicines; kit-based; high service level expectations.	Air for rapid, sea for replenishment; land transport in-country.	To clinics; field teams handle outreach or mobile care units.	Lead time, service level, stock-outs; medical quality control enforced.	Conflict zones; redundant supply plans, security negotiations, buffer stocks.	Reducing air freight; solar power; waste control; exploring greener practices.
Direct Relief	FEFO/FIFO; strict expiration controls; automated warehouse management.	Air and sea globally; trucks domestically; uses commercial carrier partnerships.	Delivered to partners; they handle final distribution to beneficiaries.	Delivery times, shipment volumes, response hours; tracked in SAP/GIS.	Warehouse has disaster resilience features; partners vetted for storage capability.	Solar-powered HQ; high efficiency, minimal waste; no explicit climate pledges.
ICRC	FEFO/FIFO; service levels based on item demand stability; safety stock maintained.	All transport modes; specialized air ops for conflict zones; efficient sea/land use.	Own convoys or local Red Crescent delivery; adapts to access/security challenges.	Procurement time, delivery time, service level tracked; robust logistics ERP.	Negotiates humanitarian access; diversified supply chain; financial buffer funds.	Eco-packaging, sea freight prioritization, solar-powered facilities, sustainability integrated.

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Feature	Inventory Policy	Transportation Modes	Last-Mile Strategy	KPIs & Tracking	Risk Management Approach	Sustainability Focus
IFRC	FIFO/FEFO; hub stock scaled to 20k+ people; periodic restocking post-response.	Air for speed, sea for volume; land fleets managed regionally.	Delivery by local Red Cross/Crescent; IFRC supports logistics up to country level.	Response speed, delivery volume, procurement cycle, warehouse accuracy tracked.	Disaster risk insurance, logistics diversification, security training, local empowerment.	Green Logistics Guide; climate charter signature; sustainable fleet/procurement practices.

Table 4.2: Comparison of Humanitarian Supply Chain Organization Structures - Part 2

## 4.2. Ranking

Following the general **HSC** analysis, we now proceed with the selection of the most significant cases through the application of the **AHP** (Analytic Hierarchy Process). This well-established methodology for addressing complex decisions enables structuring the selection process by systematically comparing both qualitative and quantitative variables. As previously mentioned, the application of the **AHP** was carried out using two separate matrices: one focused on natural disasters and another specifically concerning conflicts.

The matrices used for the evaluation allow assigning differentiated weights to the considered variables, reflecting the relative importance attributed by experts in the humanitarian response context.

### Natural Disasters Matrix:

	Indicator	Fatalities	IDPs	Area	Newspaper Articles	Damage Cost
Indicator	1	0.75	0.25	3	2	0.5
Fatalities	1.33	1	1	2	2	1.25
IDPs	4	1	1	3	2	1
Area	0.33	0.5	0.33	1	0.75	1
Newspaper Articles	0.5	0.5	0.5	1.33	1	1
Damage Cost	2	0.8	1	1	1	1
<b>TOTAL</b>	<b>9.17</b>	<b>4.55</b>	<b>4.08</b>	<b>11.33</b>	<b>8.75</b>	<b>5.75</b>

Table 4.3: Input Matrix for Natural Disaster

### Conflict Matrix:

	Indicator	Fatalities	IDPs	Area	Newspaper Articles
Indicator	1	1	1	5	2
Fatalities	1	1	1	5	2
IDPs	1	1	1	5	2
Area	0.2	0.2	0.2	1	2
Newspaper Articles	0.5	0.5	0.5	0.5	1
<b>TOTAL</b>	<b>3.7</b>	<b>3.7</b>	<b>3.7</b>	<b>16.5</b>	<b>9</b>

Table 4.4: Input Matrix for Conflict

In the matrix concerning natural disasters, the priority given to **IDPs**, the number of **Fatalities**, and the **Logistics Indicator** clearly emerges. These are followed, in decreasing order of importance, by the **Damage Cost**, the media coverage of the event, and, lastly, the geographical extent of the affected area. Although the latter might initially appear intuitively significant, its impact proves to be lower because a vast geographical expanse without high population density does not necessarily entail significant logistical or operational complexities for the humanitarian response.

The matrix regarding conflicts shows a similar hierarchy of variables to that of natural disasters, albeit with a noticeably more balanced distribution of weights. The variables **IDPs**, **Fatalities**, and the **Logistics Indicator** share equal importance, mirroring the uniform consideration attributed to these elements in assessing the severity of a conflict. Media coverage, while slightly lower in weight, remains a relevant factor for evaluating global perception of the event and the consequent international mobilization.

After rigorously applying the **AHP**, the following weighted average values were computed:

**Natural Disasters (Consistency Ratio = 0.066):**

- Indicator: 0.153
- Fatalities: 0.205
- IDPs: 0.261
- Area: 0.096
- Newspaper Articles: 0.115
- Damage Cost: 0.169

**Conflicts (Consistency Ratio = 0.0795):**

- Indicator: 0.267
- Fatalities: 0.267
- IDPs: 0.267
- Area: 0.089
- Newspaper Articles: 0.109

The values obtained for both matrices display a **Consistency Ratio** below the critical threshold of 0.1 established by Saaty, confirming the methodological coherence and reliability of the assessment.

To finalize the ranking, the final scores were calculated and normalized on a scale from 0 to 100. Subsequently, the cases were divided into three groups: **Must Have**, **Should Have**, and **Won't Have**, as described in section 2.1.4. Below are Tables 4.5 and 4.6 for natural disasters and conflicts, respectively. The row colors indicate each entry's category: green for **Must Have**, yellow for **Should Have**, and red for **Won't Have**.

#### 4.2.1. Natural Disaster Ranking:

Disaster Type	Year	Country	Score - Norm
Floods	2022	Pakistan	100.00
Earthquakes	2023	Turkiye, Syria	86.49
Floods	2020	Bangladesh, India, Pakistan	72.61
Floods	2019	India, Bangladesh	53.69
Floods	2020	Honduras, Nicaragua, Guatemala, USA, Cuba	51.58
Earthquakes	2015	Nepal	49.28
Floods	2016	Philippines, China	43.75
Floods	2020	China	43.74
Floods	2015	India	36.32
Floods	2018	China, Philippines	35.45
Floods	2016	USA, Cuba	34.12
Floods	2021	Philippines, Vietnam	33.67
Floods	2022	China, Pakistan	30.81
Floods	2022	Nigeria	30.12
Floods	2017	Cuba, USA	29.08
Floods	2019	China, Philippines	27.78
Floods	2021	China	27.13
Earthquakes	2017	Mexico	26.21
Floods	2018	India	26.11
Floods	2021	India	26.10
Earthquakes	2015	Afghanistan	26.09
Floods	2020	Philippines, Vietnam	25.80
Earthquakes	2023	Afghanistan	25.19
Earthquakes	2021	Haiti	25.02
Earthquakes	2022	Afghanistan	23.41

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Disaster Type	Year	Country	Score - Norm
Earthquakes	2023	Morocco	22.63
Earthquakes	2017	Iran	21.47
Earthquakes	2023	Nepal	20.08
Earthquakes	2018	Indonesia	18.26
Volcanic eruption	2019	Papua New Guinea	17.90
Volcanic eruption	2021	Dem. Rep. of Congo	17.77
Earthquakes	2018	Indonesia	16.38
Earthquakes	2016	Ecuador	16.01
Earthquakes	2019	Albania	15.85
Wildfires	2023	Canada	15.04
Earthquakes	2018	Papua New Guinea	13.99
Volcanic eruption	2010	Indonesia	11.89
Wildfires	2020	Syria, Israel and Palestine	11.58
Volcanic eruption	2020	Philippines	11.28
Earthquakes	2022	Indonesia	11.27
Earthquakes	2016	Indonesia	10.37
Earthquakes	2021	Indonesia	10.28
Volcanic eruption	2018	Indonesia	10.09
Earthquakes	2016	Italy	8.35
Earthquakes	2024	Japan	8.05
Wildfires	2018	United States of America	6.00
Earthquakes	2023	China	5.95
Wildfires	2018	Greece	5.34
Earthquakes	2020	Greece, Turkiye	5.34
Wildfires	2021	Greece	3.09
Wildfires	2019	United States of America	2.79
Wildfires	2022	United States of America	2.29
Earthquakes	2016	Taiwan	0.60
Wildfires	2019	Spain	0.00

Table 4.5: Natural Disaster Ranking

#### 4.2.2. Conflict Ranking:

Event Name	Year	Country	Score - Norm
Afghanistan war	2001	Afghanistan	100.00
Iraq ISIS war	2011	Iraq	88.88
Russian-Ukrainian War	2014	Ukraine	75.77
Kivu conflict	1990	Democratic Republic of the Congo	72.02
Sudan Civil War	2013	Sudan	66.72
Yemen Civil War	2014	Yemen	65.43
Somalia civil war	1991	Somalia	60.10
Syrian civil war	2011	Syria	58.57
Tigray War	2020	Ethiopia	51.86
South Sudan Civil War	2011	South Sudan	19.66
Civil Conflict (FARC)	1960	Colombia	16.24
Boko Haram Insurgency (Nigeria)	2009	Nigeria	14.68
	2016	Burkina Faso	14.64
Israel-Palestine Conflict	1948	Palestine	0.00

Table 4.6: Conflict Ranking

## 4.3. Case Studies

### 4.3.1. Nepal Earthquake 2015

#### Event

In 2015, Nepal was hit by two violent earthquakes. The first, on April 25, had a magnitude of 7.8 and had its epicenter in the Gorkha region, about 80 km northwest of the capital Kathmandu. The second earthquake, with a magnitude of 7.4, occurred on May 12, with its epicenter near the city of Lamjung, about 80 km northeast of Kathmandu. Both earthquakes were characterized by strong seismic intensity, followed by numerous aftershocks in the following days.

#### Aftermath

The earthquakes had devastating consequences, affecting nearly a third of Nepal's population, which at the time numbered about 28.2 million. The confirmed victims were over 8,700, to which are added thousands of injured and missing. The tremors affected both



of the affected communities. The education system has also suffered a significant disruption: thousands of schools have been destroyed or declared uninhabitable, forcing children and young people to temporarily give up education or continue it in improvised spaces. Finally, the need to restore livelihoods has emerged strongly, particularly in rural areas where agriculture was the main source of income. The loss of crops, tools and agricultural resources has seriously compromised the ability of many families to provide for their basic needs.

## HSC

In the case of the earthquake in Nepal, managing the humanitarian supply chain was confronted with numerous operational challenges. One of the main difficulties was the low level of logistics infrastructure in the country, which was strongly influenced by both limited economic development and the impervious nature of the territory. Nepal is in fact characterized by a predominantly mountainous landscape, with many communities located in isolated areas that are difficult to reach even under normal conditions. This scenario has been further exacerbated by the severe damage caused by the earthquake to existing infrastructure, including roads, bridges and airstrips, making many areas completely inaccessible. In addition, the imminent arrival of the monsoon season has increased the risk of landslides and landslides, further complicating the transport of goods and the organization of logistics operations.

In this extremely complex context, a fundamental role has been played by the local population. In particular, the inhabitants of mountain areas, including Sherpas and other ethnic groups accustomed to moving in inaccessible environments, have actively collaborated with humanitarian organizations for the transport and distribution of aid. In the absence of viable communication routes, pack animals have often been used to reach the most remote villages, making a decisive contribution to overcoming logistical barriers.

Aid was provided by numerous humanitarian organizations, but the management of logistics in its final phase was centralized by the Nepalese government. To facilitate coordination, a *Logistics Cluster Coordination Cell* has been established in Kathmandu and in the two main operational districts: Gorkha and Sindhupalchok. This structure was tasked with supporting the general organization of logistical operations, facilitating the exchange of information between the various actors involved, in particular NGOs. The periodic meetings of the Logistics Cluster made it possible to update and review operational plans, share data, analyze emerging critical issues and identify the main bottlenecks.

The collaboration between the Logistics Cluster and the national authorities was also

fundamental, in particular for the coordination between civilian and military actors. This has made it possible to optimize the use of air resources (both national and international) to reach the most isolated areas. To ensure effective humanitarian action, the Cluster collected, consolidated and shared information on ongoing activities, available infrastructure, customs procedures, access restrictions and storage and transport capacities in the affected areas. A GIS (Geographic Information Systems) capacity has also been activated to map traffic restrictions and provide useful tools for the decision-making process.

Another important initiative was the activation of a Logistics Cluster base in Kolkata, with the aim of facilitating the transit of aid from India to Nepal by land. A *Humanitarian Staging Area (HSA)* has been set up at Kathmandu airport, connected to a network of logistics hubs distributed in the affected districts. To increase its operational capacity, an additional storage center has been set up in Dhulikhel, in the district of Kavre, useful for decongesting the capital and managing international air shipments before their distribution.

At the regional level, several logistics bases have been created:

- Deurali (Gorkha district): in support of operations in the western region, in particular air operations;
- Chautara (Sindhupalchok district): to accelerate distribution in the eastern region and also support local humanitarian flights;
- Bharatpur (Chitwan district): for the management of overland flows from India, acting as a hub for cargoes from Nepalgunj, Belaihya and Birgunj;
- Birgunj (Parsa district): with the function of a rapid transit point for aid entering from the Indian border.

Finally, numerous light logistics centres and temporary warehouses have been installed in the vicinity of the affected areas, to improve storage capacity and facilitate the final distribution of aid to the population.

Positive elements	Negative elements
High cooperation of the local population: Sherpas and pack animals	Weak infrastructure before the earthquake and destruction of some of them after
High coordination of aid	Climatic difficulties: arrival of the monsoon season
Activation of regional logistics hubs	Mountainous area: some remote areas remained inaccessible
Using MSU to manage the last mile	Single point of international powered access: congestion
Rapid adaptation of logistics thanks to well-trained staff.	Limited internal warehouse space management led to congestion.

Table 4.7: Nepal Case Elements

### 4.3.2. Pakistan Flood 2022

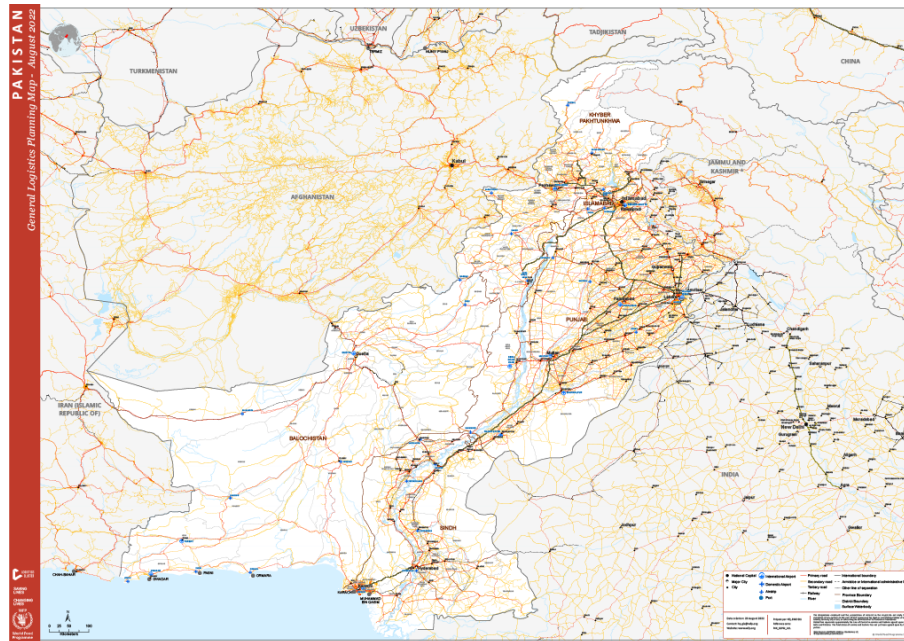


Figure 4.4: Pakistan 2022 Concept of Operations [22]

### Event

In August 2022, Pakistan was hit by an exceptionally intense and prolonged monsoon, which brought rainfall well above the seasonal average. The month of August saw a national average of about 390 mm of rainfall, an increase of 243% compared to the average

of the last 30 years. In particular, the provinces of Sindh and Balochistan were the most affected, with rainfall increasing by 726% and 590% respectively compared to normal, making August 2022 the wettest month ever for both regions. The wettest day of the month was August 19, when Padidan (Sindh) recorded 355.0 mm of rain, also becoming the wettest place with a monthly total of 1228.5 mm. The huge amount of water carried by the monsoon, amplified by climate change that has contributed to the melting of more than 7,000 glaciers in mountainous regions, has caused numerous rivers to overflow, including the Indus, Sutlej, Kabul and Chenab, submerging large areas of Pakistani territory, including the major cities of Karachi, Hyderabad, Quetta, Sukkur, Multan and Dera Ghazi Khan. In total, an area of about 85,000 km<sup>2</sup> was flooded, equivalent to more than twice the area of Switzerland.

## Aftermath

Around 30 million people were affected by the floods in August 2022, of whom 8 million became displaced persons (IDPs). There were 1,760 confirmed victims, while over 2 million homes were destroyed or severely damaged. Infrastructure, which is critical for emergency response, has been severely compromised, with 436 bridges destroyed and more than 13,115 km of roads damaged, slowing down rescue operations. The total economic loss, of more than \$40 billion, is the largest estimate of damage ever made in history following a natural disaster. Agriculture has also suffered enormous damage, with about 4.4 million acres of crops and orchards submerged, and over 1.1 million head of livestock dead. The resulting economic and humanitarian crisis has made recovery extremely difficult.

Several interventions were required to ensure the safety and survival of the population, but one of the top priorities was to provide safe shelters for those who had lost their homes or had been forced to flee the waters. Temporary shelters, such as tents and makeshift structures, have become essential to protect people from harsh climatic conditions. The supply of drinking water has been a crucial need, as floods have contaminated water sources, exposing the population to serious health risks. Ensuring access to safe food and clean water has been critical to preventing disease and ensuring survival. Health facilities have played a key role in addressing diseases related to stagnant water and poor sanitation. The crisis has also had a devastating impact on the education system: many schools have been destroyed or declared unfit for use, disrupting the education of millions of children. Finally, the resumption of agricultural activities has been essential, particularly in rural areas, where the loss of crops and the death of millions of livestock have compromised the sources of income of many families.

## HSC

The emergency response in Pakistan in 2022 faced significant logistical challenges related to the country's geography and climate. Pakistan is in fact exposed to floods due to the presence of large rivers, such as the Indus, which cross large areas of the territory, and to the heavy monsoon rains typical of its climatic zone. Although the logistical infrastructure is of a decent level, it has proved to be partly unsuitable to withstand the intensity and scale of the crisis, especially in the areas most affected by the floods. The main entry points for humanitarian operations were the ports of Karachi and Port Qasim, which are crucial for the maritime flow of goods, as well as the international airports of Islamabad, Lahore, Peshawar and Karachi, which ensured the air movement of urgent aid.

A crucial element in the coordination of aid was represented by the network of Humanitarian Response Facilities (HRF), permanent structures strategically distributed throughout the territory, in areas not directly affected by the flood. These facilities are a joint initiative between WFP and the Government of Pakistan and have been instrumental in ensuring the storage, sorting and rapid distribution of humanitarian goods. Their distribution throughout the territory is illustrated in the following table:

Locality	Size (m <sup>2</sup> )
Muzaffargarh	3.200
Lahore	4.400
Sukkur	3.200
Hyderabad	2.160
Quetta	4.400
Peshawar-Jalozai	4.400
Muzaffarabad	1.960
Gilgit	960

Table 4.8: Pakistan Warehouse Location and Capacity

These structures have made possible a more widespread and efficient response, also supported by the availability of commercial warehouses in the main cities and industrial areas, with spaces of various sizes, from prefabricated buildings to reinforced concrete warehouses, and uncovered courtyards. In parallel, WFP has operated additional own warehouses for the storage of food and essential materials, often equipped with temperature-controlled units, distributed in centres such as Peshawar, Karachi, Quetta and Islamabad. In addition, the cold chain has been ensured by the collaboration between Maersk and

the Pakistani government, which is essential for the storage of sensitive medicines and foodstuffs.

The distribution of aid has encountered major obstacles in the "last mile delivery" phase, i.e. delivery to the most remote or isolated areas. Destroyed roads, interrupted railways and high water levels have required alternative solutions: among these, the use of boats has proved decisive in reaching the villages surrounded by water. In some areas, light vehicles and secondary routes, such as the Mehran Highway, were used to overcome roadblocks and continue operations.

The Pakistani government has supported humanitarian intervention by exempting supplies to the Prime Minister's Flood Relief Fund from customs duties and has established the National Flood Response and Coordination Centre (NFRCC) to ensure unified and efficient resource management. The European Union has also provided support by activating the Civil Protection Mechanism (EUCPM) to send shelter, food, medicine and heavy machinery.

Positive elements	Negative elements
Humanitarian Response Facilities Network	Damage to infrastructure before and after the earthquake
WFP and Government of Pakistan collaborate in logistics management	Monsoon area and proximity to large rivers
Effective cold chain management through Maersk	Access restrictions in some areas due to security reasons or local political instability
Use of boats and alternative means for the last mile	Emergency extended over time due to continuous rains

Table 4.9: Pakistan Case Elements

### 4.3.3. Ukraine-Russian War 2022

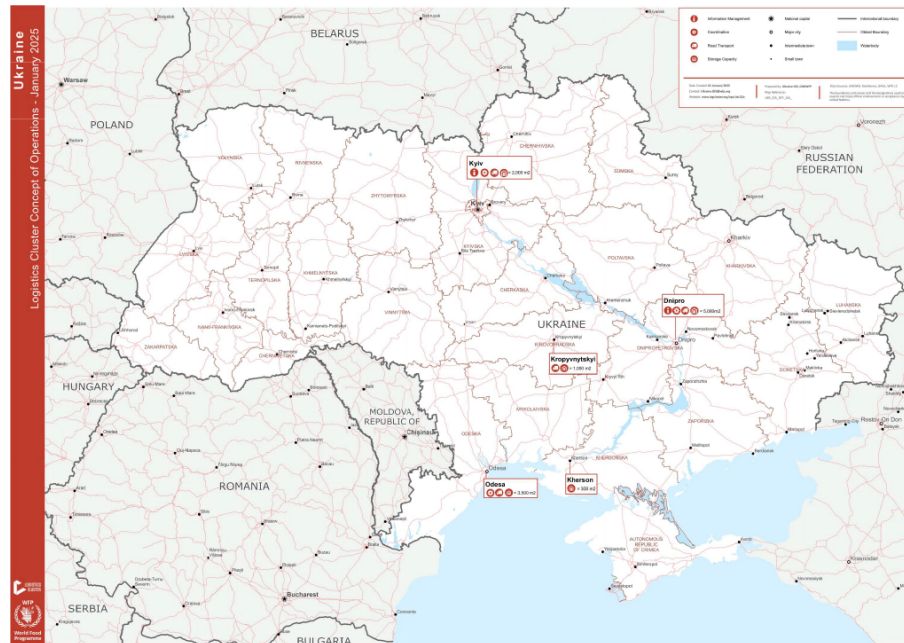


Figure 4.5: Ukraine 2025 Concept of Operations [21]

## Event

After weeks of rising tensions and the escalation of the conflict in eastern Ukraine, which has been underway since 2014, Russia launched a full-scale invasion of the country on February 24, 2022. Military operations began with missile strikes on strategic targets throughout Ukrainian territory, including airports, military bases, ammunition depots and critical infrastructure. Soon after, Russian troops entered the country by land, air and sea, initiating a coordinated maneuver on several fronts. The offensive developed mainly from three directions: from the north, crossing the border with Belarus; from the east, through the separatist regions of Donetsk and Luhansk; and from the south, starting from Crimea, annexed by Russia in 2014. Russian convoys advanced rapidly towards strategic cities, including Kharkiv, Mariupol, Kherson and the capital Kyiv.

The Ukrainian military, already on high alert, reacted by mobilizing its armed forces across the country, strengthening defenses in major cities, and organizing resistance points in threatened territories. Since the first hours of the conflict, Ukrainian troops have put up strong resistance, hindering the Russian advance and defending the main logistical and strategic junctions. In the space of a few days, the conflict became the largest armed clash in Europe since World War II, marking a dramatic turning point in the continent's recent history.

## Aftermath

Since the beginning of the conflict in Ukraine, the total number of dead and wounded is estimated to have exceeded one million, including more than 300,000 victims. In addition, in 2022 alone, more than 16 million people in Ukraine were forced to leave their homes, creating one of the largest displacement crises in Europe. The consequences of the conflict have had a devastating impact on the territory and the population. According to the most recent estimates, at the beginning of 2025 the total damage caused by the war amounted to about 524 billion dollars. More than 330,000 homes have been destroyed, while the country's ability to generate energy has suffered a 70% loss, affecting access to electricity in many regions, especially during the winter months. Transport infrastructure has also suffered extensive damage: around 25,000 kilometres of roads and 344 bridges have been destroyed or rendered unusable, severely hampering internal connections and supplies. The supply of essential goods was severely impaired or disrupted in numerous areas, due to extensive damage to the supply chain and logistics network.

## Necessity

In addition to basic needs for food, drinking water and medicines, humanitarian needs in Ukraine include essential goods such as blankets, thermal clothing and heating sources. The destruction of energy infrastructure has deprived millions of Ukrainians of domestic heating, exposing children, the elderly and vulnerable people in particular to serious risks. The devastation of homes has increased the number of displaced people, making shelter an urgent priority. In addition, managing safe transport for people from war zones is crucial, especially for those in need of urgent evacuation. No less important is the provision of medicines and rescue kits, which are essential for the treatment of wounds from shelling, burns and other conflict-related injuries, in a context where health facilities are often overloaded or damaged. These goods and services are vital for the survival and protection of those affected.

## HSC

Following the Russian invasion of Ukraine, the Logistic Cluster has taken on a central role in the coordination of humanitarian logistics operations, in a context marked by high operational risk. The initial response, organized in the first days of the conflict (25 February – 5 March), saw the implementation of a cross-border logistics network in close collaboration with the governments of Poland, Ukraine and Romania, and with the support of more than 60 international humanitarian organizations. Strategic storage hubs

were quickly activated in Rzeszow, Lviv, Warsaw and Lublin, as well as the establishment of safe entry points into Ukraine to ensure the continuity of logistics flows. However, the infrastructural conditions damaged or blocked by the armies, together with the closure of airspace and the inaccessibility of seaports, immediately posed significant challenges. In particular, the reluctance of Polish transporters to cross the border for insurance reasons, and the impossibility for Ukrainian transporters to leave the country, have exacerbated handling difficulties.

During the first two months, thanks to an investment of 18.8 million euros, a push strategy was adopted, with the expansion of storage capacity in several Ukrainian cities (including Kiev, Dnipro, Odessa, Kropyvnytskyi) and the creation of a customs one-stop-shop in Rzeszow. Numerous transport missions were facilitated in heavily affected areas such as Sievierodonetsk, Chernihiv and Mykolaiv. The Cluster has also established a Medical Logistics Working Group, to support partners in the management of medical supplies, which are particularly critical in the initial absence of reliable refrigerated solutions. Only since May, in fact, has the safe transport of pharmaceutical products below 30°C been guaranteed, while for the cold chain between +2°C and +8°C, passive containers with limited autonomy have been used.

In the second half of the year, the focus shifted to optimising the logistics network, reaching more than 70,000 m<sup>3</sup> of aid delivered in twelve Ukrainian oblasts. A progressive reduction in storage capacities and the closure of some sites have allowed a more efficient use of available resources, guided by an accurate gap and needs analysis (GNA). Organizations such as Atlas Logistique-HI and the ICRC have also made important contributions, providing key logistical resources such as hubs in Dnipro, Kharkiv, Vinnytsia and Mykolaiv. The arrival of dry cold, typical of the winter months in Central Europe, has placed additional pressure on the supply chain, exacerbating already critical conditions in many areas, especially in isolated areas or those with compromised infrastructure. These difficulties have been compounded by a persistent fuel shortage in Ukraine, which has hampered the transport and distribution of humanitarian aid. In this scenario, coordination, operational agility and cooperation between humanitarian actors have proven to be key elements in ensuring an effective and timely response to the humanitarian crisis in Ukraine.

Positive elements	Negative elements
Good infrastructure before the war	Infrastructure destroyed or occupied by armies
Coordination of the Logistic Cluster and support of many associations including IRC and Atlas-Logistique-HI	Restricted airspace and limited access to seaports
Adoption of a push strategy to speed up aid at the beginning of the crisis	Fuel shortage
Resource optimization in the second half of the year thanks to GNA analysis	Arrival of dry cold
Large mobilization of funds	Limited access points in the country
Logistics and procurement units operated with flexible mandate, boosting speed.	Insufficient contingency planning for temperature-sensitive supplies

Table 4.10: Ukraine Case Elements

### 4.3.4. Democratic Republic of the Congo War 2012

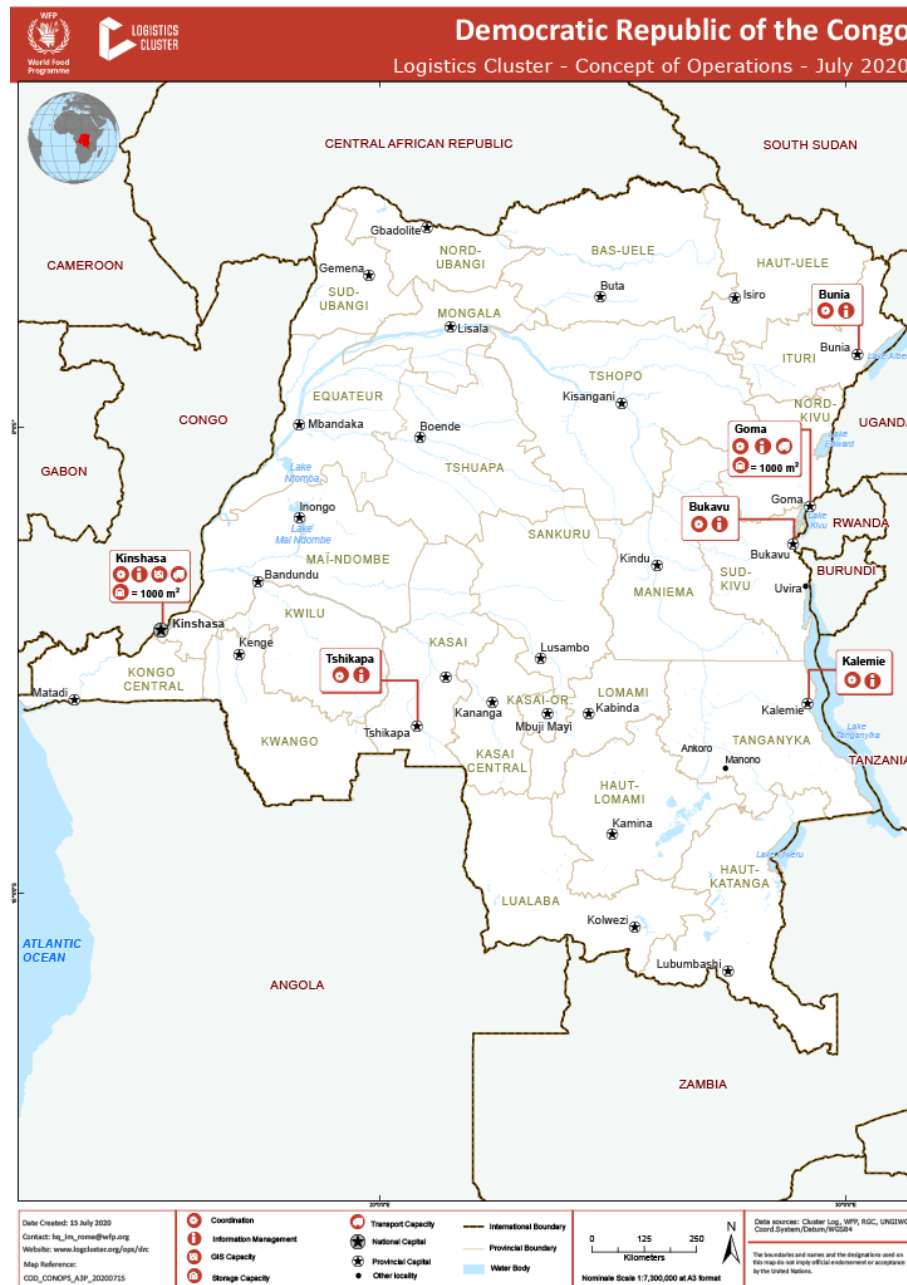


Figure 4.6: DRC 2025 Concept of Operations [23]

## Event

The conflict in the Democratic Republic of Congo (DRC) has its roots in 1996 with the First Congo War, but it has taken on a prolonged and cyclical dimension that continues today. After the Second Congo War (1998–2003), the country never really achieved lasting stability, particularly in the eastern provinces, where the absence of effective state control

allowed the proliferation of more than 120 armed groups. In recent years, there has been a new, worrying escalation of violence, especially since 2021 with the return to the scene of the March 23 Movement (M23). This rebel group, already known for its actions in 2012, has resumed hostilities in North Kivu, accusing the Congolese government of not respecting the peace agreements. Since 2022, the M23 has conquered significant portions of territory, and in January 2025 it even took control of the city of Goma, while in February it also occupied Bukavu, two of the main urban centers of the eastern country.

## Aftermath

Since 1998, an estimated 5.4 million people have died, largely due to malnutrition, disease and lack of access to health services, aggravated by war. As of March 2024, more than 7.1 million people are internally displaced, making this the largest displacement crisis in Africa. Eastern areas, such as Ituri, North Kivu and South Kivu, are the most affected: here the social fabric has been torn apart by decades of violence, with civilians often direct victims of armed groups. The destruction of vital infrastructure – schools, hospitals, water networks – has compromised access to essential services, while the use of explosive weapons in densely populated areas has caused massive destruction, including the damage to more than 70,000 temporary shelters in the Goma area.

## Necessity

The humanitarian needs of the population in the DRC are multiple and urgent, exacerbated by the continuing conflict, displacement and the collapse of essential services. Food assistance and nutrition are a top priority: millions of people face severe food insecurity, with acute malnutrition rates among children exceeding emergency thresholds in several provinces. Internally displaced people often live in overcrowded camps or makeshift shelters, without adequate protection from the elements. The already fragile health system is under extreme pressure: shortages of medicines, equipment and staff are compromising access to basic care, while hospitals are struggling to function due to a lack of fuel and beds. Access to safe drinking water and sanitation (WASH) is also extremely limited, increasing the risk of outbreaks such as cholera and measles. Protection needs are equally critical: civilians, especially women and girls, are exposed to violence, abuse and sexual violence on a daily basis. Displaced populations are in urgent need of food, shelter materials (such as tents, tarpaulins and blankets), non-food items (hygiene kits, utensils, mattresses), medical supplies and tools to improve sanitation. In response, in addition to material aid, cash assistance programs have been activated to allow the most vulnerable families to meet their immediate needs and to start a process of reconstruction of their

daily lives.

## HSC

Humanitarian supply chain management in the Democratic Republic of Congo (DRC) is confronted with extremely complex logistical, climate, and security challenges. Operations are concentrated in areas of high instability such as North Kivu, South Kivu and Ituri, where more than 120 armed groups are active. In these regions, humanitarian organizations face constant risks of looting, roadblocks, kidnappings and armed attacks, which compromise the safety of personnel and the smooth distribution of aid. In the past, cities such as Goma and Bukavu had been chosen by organisations such as MSF and IRC to host strategic warehouses, as they were considered sufficiently secure and close to the most affected areas. However, over the past year, both cities have been captured by the M23 armed group, making it impossible to maintain stable and secure operational facilities on site. As a result of the deterioration in security, many organizations have relocated their logistics hubs to relatively more stable areas such as Kaliemie, Bunia, Kindu, Kananga, Lubumbashi and Kinshasa, also at the expense of operational readiness. These cities, further away from the conflict fronts, allow a greater level of security for supplies and humanitarian workers. The main entry points for humanitarian goods into the country include Kinshasa International Airport (Ndjili), Lubumbashi Airport and Kananga Airport – all located in areas far from conflict zones. In addition, there is the river port of Kinshasa on the Congo River and, in some cases, land crossings with Uganda, Rwanda and Zambia. From these hubs, aid is distributed through a multimodal logistics network that includes road, air and river transport.

The Logistics Cluster, coordinated by the World Food Programme (WFP), plays a central role in ensuring cooperation between humanitarian organisations, facilitating information sharing and joint planning of logistics activities. Regular meetings are held in several operational cities to adapt strategies according to rapidly changing conditions. In a context of systematic emergency, the supply chain relies on forecasting models to estimate demand and pre-position essential goods in a timely and efficient manner. However, the infrastructural conditions remain critical: only about 5% of the roads are paved, and many arteries are inaccessible during the rainy season or occupied by armed militias, especially in the Kivu area. In these contexts, the United Nations Humanitarian Air Service (UNHAS) and river routes are crucial alternatives, although they also have limitations related to capacity, cost and environmental variability. At the local level, organizations such as UNOPS contribute to strengthening logistics by building and improving roads, bridges and structures in remote areas. The success of the humanitarian response depends on

the ability to dynamically adapt to an unstable, fragmented and ever-changing operating environment.

Positive elements	Negative elements
Real-time sharing of information on the logistics situation in the country from the Logistic Cluster	Extremely poor infrastructure before the conflict, further damaged and occupied by rebels
Multiple access points in the country	Low security for humanitarian workers in several regions
Systematic emergency, therefore possible applications of forecasting systems	Large cities near the conflict zones have fallen into the hands of the rebels
UNOPS works on improving infrastructure	Limited media impact
Adaptive warehouse planning using modular containers maintained operational resilience.	Central command structure lacked flexibility in fast-changing field conditions.

Table 4.11: DRC Case Elements

### 4.3.5. United States of America Hurricane 2017

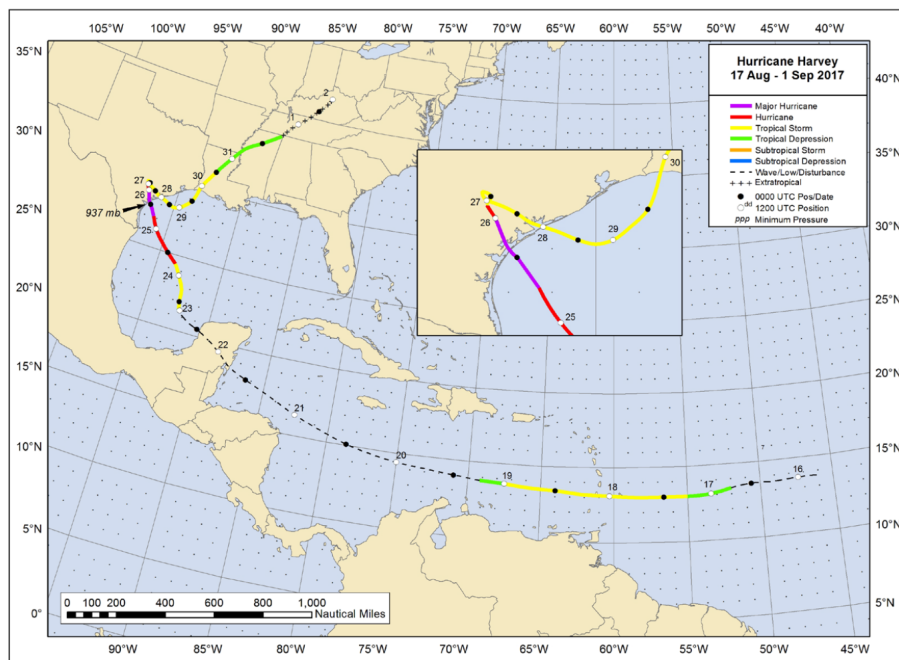


Figure 4.7: USA 2017 Hurricane Harvey Path [2]

## Event

Hurricane Harvey was a Category 4 tropical cyclone that struck the United States in August 2017, causing devastating damage in Texas, Louisiana, and other surrounding regions. On August 25, Harvey made landfall in Corpus Christi, Texas, with winds reaching 215 km/h. After hitting the coast, the hurricane continued its journey inland, crossing the southern United States and the Tennessee Valley. During its passage, Harvey caused record rainfall, with some places recording over 1,500 mm of rain, including the cities of Nederland and Groves, Texas. In addition, the hurricane generated 52 tornadoes, including 3 high-intensity tornadoes, classified as EF-4 on the improved Fujita scale.

## Aftermath

Hurricane Harvey was one of the most devastating in U.S. history, ranking as the second most expensive after Katrina, with damage estimated at about \$125 billion. With 89 deaths directly attributed to the hurricane and about 35 indirect deaths, Harvey was the deadliest hurricane in the United States in terms of direct fatalities from the 2012 Sandy storm and is the deadliest cyclone to hit Texas since 1919. The floods affected over 300,000 homes, with about 500,000 cars submerged. Roads in many regions, such as the Houston metropolitan area and southeast Texas, were completely flooded with water, including major road axes such as I-10 and I-45, which were unusable for days. The evacuations involved about 40,000 people, with over 30,000 rescues carried out. Flooding has also affected infrastructure, with thousands of homes destroyed or severely damaged, including communities around Houston, Galveston and Jefferson County. The worst-hit areas have seen record flood levels exceeded on rivers and streams, such as the Buffalo Bayou and Clear Creek. Transportation disruptions have been enormous, with more than 300,000 people losing access to electricity. Harvey has also had a significant impact on the energy sector, with numerous oil refining plants being taken out of service, causing fuel prices to rise.

## Necessity

The aftermath of Hurricane Harvey has generated a vast humanitarian emergency in the affected areas, particularly in southeast Texas. The population has faced urgent needs since the first hours of the flood: temporary shelters for more than 40,000 displaced people, food supplies and drinking water, often scarce due to the inaccessibility of communication routes and the interruption of services. Many residents lost everything and found themselves without basic necessities, including dry clothing, blankets and hygiene prod-

ucts. Sanitation conditions in overcrowded reception centres required rapid intervention to prevent the spread of disease, while the need for medical care affected both injured people and people with chronic conditions who were left without access to medicines. In addition, thousands of families have needed psychological assistance to cope with the trauma of losing their homes and uncertainty about the future.

## HSC

Following Hurricane Harvey, control of humanitarian operations was immediately taken over by the Federal Emergency Management Agency (FEMA), the federal agency in charge of emergency management in the United States. As the central coordinating body, FEMA led a massive interagency response, integrating the resources and expertise of numerous federal departments, including the Department of Health and Human Services (HHS), the Department of Energy (DOE), and the Department of Defense (DoD). The approach adopted has allowed a synergistic and widespread management of the emergency, making it possible to distribute humanitarian aid in a timely and organized manner, without having to resort to large-scale international support.

Even before the hurricane landed, FEMA had pre-positioned resources and personnel in the state of Texas, in collaboration with the Texas Division of Emergency Management and local and national actors, including nonprofits, faith-based and private sector organizations. The main emergency warehouses were located in San Antonio, Houston, Fort Worth and Austin, strategic areas considered relatively safe and well connected to the potentially affected areas. From these hubs, essential goods such as food, water, blankets, fuel and medical equipment were distributed via a multimodal network consisting of helicopters, transport planes, amphibious vehicles, boats and road convoys organised in collaboration with the private sector.

The Coast Guard has deployed over 2,000 operators with air and naval means, rescuing more than 11,000 people and over 1,300 pets. The Department of Health and Human Services has mobilized more than 1,100 health care workers, providing treatment to thousands of patients and organizing the relocation of residents from flooded homes to safe facilities, such as the Bob Bowers Civic Center in Port Arthur. The Department of Energy has partnered with electric utilities to restore power to more than 300,000 utilities, mobilizing more than 10,000 technicians from 21 states, and has authorized the use of strategic oil reserves to support the supply chain. The Department of Defense, through the Northern Command (USNORTHCOM), has performed logistical support, transport and rescue missions, contributing to the recovery of about 3,000 people.

The response was also strengthened thanks to the strong participation of the local population, who played a fundamental role in collecting and sharing information in real time. Two significant initiatives in this regard were the U-Flood app, which allowed citizens to report flooded or cleared roads via an interactive map, and the Harvey Relief and Rescue project, powered by over 500 volunteers, which used collaborative maps to coordinate rescue requests and humanitarian interventions.

Finally, the National Business Emergency Operations Center, with the involvement of over 150 private partners, supported FEMA in the management of essential services, from communications to the distribution of goods, also facilitating connectivity thanks to collaboration with telecommunications companies and social platforms.

Positive elements	Negative elements
High level of infrastructure	Climatic difficulties: event of great intensity and prolonged over time
High level of organization	Blocking of key roads due to flooding and bridge collapse
Widespread distribution of aid	Fragmentation in municipal-vs-federal command blurred operational responsibilities.
Collaborations with the private sector	Rigid procurement workflows delayed last-mile resupply flexibility.
Use of predictive systems and continuous disaster monitoring	The afflicted zones were densely populated
Centralized coordination by a dedicated body: FEMA	–
Strong cooperation of the local population	–

Table 4.12: United States Case Elements

#### 4.4. Factors Analysis

In the face of large-scale disruptive events, such as natural disasters or armed conflicts, the success of humanitarian operations depends on a nuanced understanding of the variables that govern both the needs of affected populations and the capabilities of those providing assistance. To make sense of this complexity, this thesis introduces two key analytical concepts: **Humanitarian Aid Demand** and **Humanitarian Aid Supply**. These terms borrow intentionally from business and supply chain management, forming

a **metaphorical parallel** between the commercial world and the humanitarian context. While businesses operate to meet consumer demand with product supply, humanitarian systems must respond to urgent needs with life-saving assistance.

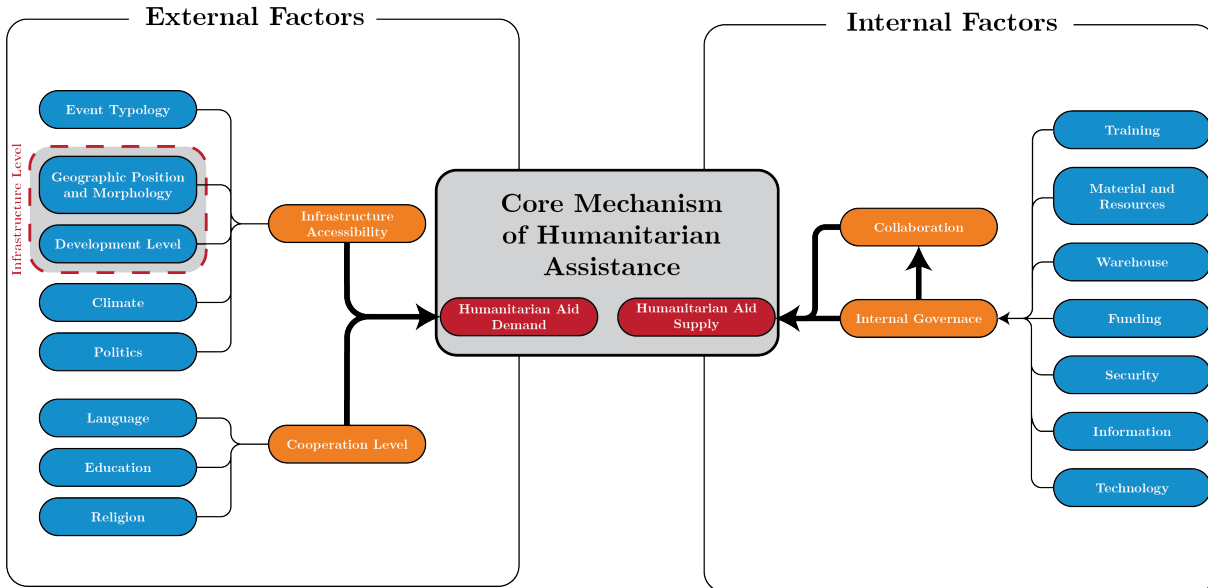


Figure 4.8: Causal Model of Humanitarian Assistance Dynamics

- **Humanitarian Aid Demand** refers to the level at which a territory impacted by a disruptive event requires and is able to receive humanitarian support. This includes the severity of the event’s consequences, such as displaced populations, infrastructure collapse, and medical emergencies, as well as the region’s capacity to allow aid access, which may be hindered by political instability, geographic barriers, or lack of local governance.
- **Humanitarian Aid Supply** denotes the volume and efficiency of aid provided by NGOs, international organizations, and other actors. This includes not only physical goods, but also logistics systems, trained personnel, information, and financial resources. The adequacy of this supply depends on both internal capabilities—like warehousing, transport capacity, and funding—and external conditions that affect delivery.

The use of these business-derived terms enables a clearer interpretation of humanitarian logistics performance, especially in dynamic, high-stakes environments. As represented in fig. 4.8, Humanitarian Aid Demand and Supply lie at the center of a broader ecosystem influenced by numerous **external** and **internal factors**. External factors—such as climate, terrain, infrastructure, and political context—shape both the intensity of need

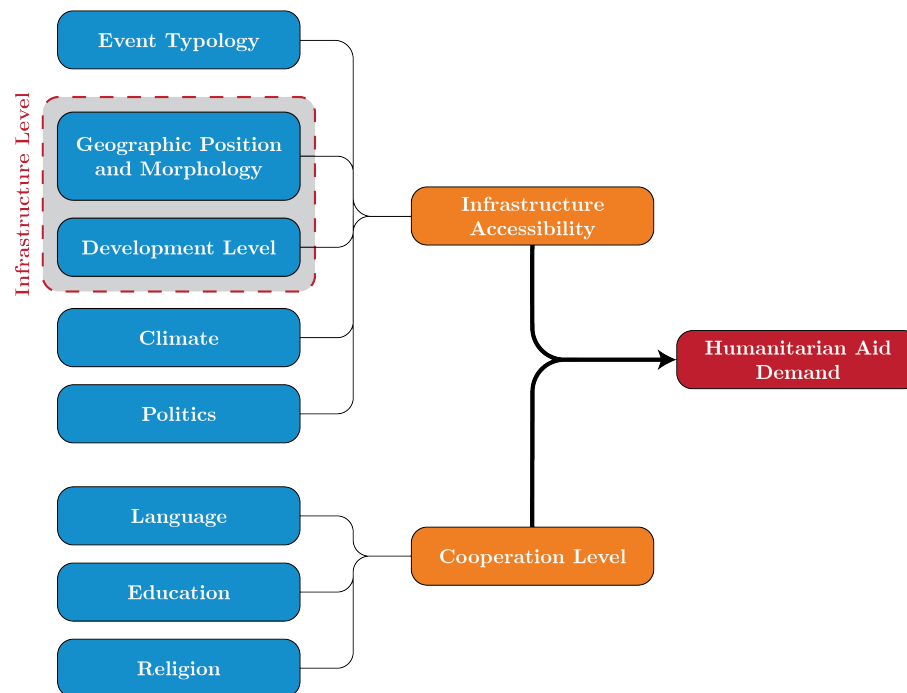


Figure 4.9: External Factors

and the feasibility of aid delivery. Internal factors, by contrast, are tied to the operations, coordination structures, and governance models of humanitarian organizations.

In the analysis that follows, we will investigate how these external and internal variables influence the balance between Humanitarian Aid Demand and Supply. Through selected case studies, this section aims to highlight the conditions under which humanitarian responses succeed—and where they fall short—providing insight into how resilience and efficiency can be strengthened in future operations.

#### 4.4.1. External Factors

In humanitarian supply chain operations, the external context is a crucial element in determining the effectiveness of interventions. Several geographical, political, economic and cultural factors can hinder or facilitate **the ability to receive aid** in crisis areas. For this reason, a thorough analysis of the surrounding environment is essential to ensure effective logistical planning and timely response to emergencies. In this context, two main elements must be taken into account: **the accessibility of infrastructure** and the **level of cooperation of the local population**. The presence of accessible infrastructure allows the rapid transfer of resources to the affected areas and the preparedness of the local population guarantees adherence to humanitarian efforts.

**The accessibility of infrastructure** in a humanitarian emergency depends on several elements, but the main parameters to be taken into account are: **climatic factors**, the **level of existing infrastructure** and **political factors**. Weather phenomena, such as heavy rain or snowfall, can seriously compromise the road network, making roads and bridges impassable, or limiting the use of ports and airports. At the same time, the quality and capillarity of pre-existing infrastructures play a fundamental role: in many contexts, especially in developing countries, logistics networks are fragile or insufficient to support a sudden influx of goods and means. Finally, human factors, such as political stability, existing regulations, local bureaucracy and the level of coordination between authorities and humanitarian actors can significantly facilitate or hinder logistical operations. Analyzing these elements is essential to identify critical issues and improve the efficiency of logistics flows.

**The level of cooperation**, as shown in the diagram, is influenced by factors that depend closely on the local population. Language **barriers** can hinder communication between responders and the community, making it difficult to convey vital information about health treatments or hygiene practices. In addition, **religious beliefs**, traditional practices and distrust of external institutions can be obstacles to full acceptance of the proposed treatments. The **level of education** and the perception of the role of modern medicine also plays a key role in determining how much a population is willing to cooperate with emergency responders. For this reason, it is crucial that humanitarian actors adopt sensitive cultural strategies and promote dialogue with community leaders to facilitate the acceptance of aid and improve the effectiveness of interventions.

In light of these aspects, the individual factors that influence the accessibility of infrastructures and the level of cooperation of the local population will be analyzed in detail in the following paragraphs, highlighting their operational implications in humanitarian supply chain operations.

#### 4.4.2. Accessibility of infrastructure

##### Infrastructure level

The level of infrastructure already in place in a country affected by an emergency has a direct and significant impact on the efficiency and speed of the humanitarian response. One of the measures used to assess the quality of a country's logistics system is the LPI, which reflects a country's ability to manage logistics flows effectively. There is a correlation between a high LPI and the ability to provide aid in a timely and efficient manner: a country with a high LPI has robust and well-developed infrastructure, such

as roads, railways, ports, and airports, which facilitates the rapid transport of goods and people, thus reducing response times in emergency situations. On the other hand, a low LPI indicates an inadequacy or weakness of logistics infrastructure, with a direct negative impact on the speed and effectiveness of the response. In these cases, logistical operations can be slowed down by damaged or poorly maintained roads, congested airports or unable to handle large volumes of aid, and inoperable ports.

To understand what has just been said, it is possible to analyze two calamities of the last decade: the Hindu Kush earthquake (2015) and the Amatrice earthquake (2016).

In 2016, Italy was ranked 21st globally with an LPI of 3.76. When the country was hit by the devastating earthquake rated at grade X-XI on the Mercalli scale, the advanced level of its infrastructure contributed decisively to containing the effects of the catastrophe. The resilience of the Italian logistics system allowed a rapid distribution of aid, facilitated relief to the most isolated areas and guaranteed efficient management of resources, despite the vastness of the damage. An emblematic example of this efficiency is represented by the "three-eyed bridge" of Amatrice, seriously damaged structurally by the earthquake. Thanks to the timely intervention of the Italian Army and the Civil Protection, the bridge was reinforced and made usable again within just eight days.

This extraordinary speed of restoration highlights not only the operational capacity of the emergency forces, but also the efficiency and readiness of Italian infrastructures in responding to critical situations, ensuring the continuity of connections and accessibility to the affected areas.

In contrast, Afghanistan ranked 150th with an LPI of 2.14 when the violent earthquake struck the country in 2016. Infrastructural deficiencies emerged dramatically: many roads were impassable, connections between rural areas and major logistics centers were weak, and airport facilities were unable to handle the volume of international aid received. These critical issues significantly slowed down the distribution of humanitarian aid, compromising the timeliness of operations and worsening the conditions of the affected populations. The difficulty in accessing the most remote areas and the inability to quickly manage the arrival of help have made the emergency even more complex, highlighting how a low LPI can severely hinder the ability to respond to a crisis effectively.

After understanding that the level of infrastructure has a direct impact on the effectiveness of humanitarian logistics systems, it is essential to understand the reasons that determine a different level of infrastructure. Firstly, the geography and morphology of the territory play a crucial role: areas characterized by mountainous, rugged or difficult to access terrain require more articulated logistical solutions, both in terms of planning and the means

used. Added to this is the level of economic development of the country, which is another determining factor. Countries with advanced economies generally have modern, extensive and well-maintained infrastructure, capable of guaranteeing effective support to logistical operations. On the contrary, in developing countries, the lack of economic and technical resources can hinder the construction and maintenance of adequate infrastructure, thus compromising the timeliness and efficiency of humanitarian interventions.

### Morphology of the territory and geographical position

The natural characteristics of the territory, such as the presence of mountain ranges, desert areas, swampy or flood-prone areas, can make the construction, maintenance and expansion of essential infrastructures such as roads, airports and railways particularly complex. Geographical isolation, typical of island regions, can limit accessibility and affect both the quality and availability of infrastructure. In addition, factors such as seismic, volcanic and hydrogeological activity pose significant challenges to the design and safety of works, making it necessary to adopt advanced technologies and specific materials to ensure their resilience.

A context in which geography imposes stringent constraints is Nepal, characterized by a predominantly mountainous territory, with numerous peaks that exceed 7,000 meters. In an environment dominated by the Himalayan chain, creating secure and continuous infrastructure networks is extremely complex. Sharp gradients, steep slopes and unstable terrain hamper the construction of roads, railways and airports, requiring complex engineering solutions. In addition to this, there are landslides, landslides and avalanches that frequently hit the territory during the monsoon or winter periods, putting the stability of existing structures at risk and requiring frequent consolidation works. Logistics is further slowed down by limited access to many inland areas, which makes it difficult to transport building materials and machinery. The design phase is also influenced by the conformation of the territory, since each intervention must be adapted to the morphological and environmental specificities of the individual valleys or slopes.

Moving towards territories with completely different soil conditions, marshy areas pose equally significant obstacles. Here, soft, water-saturated soils hinder the construction of solid foundations for roads, bridges and buildings. The constant moisture of the soil prevents soil stabilization, forcing the use of specific technologies such as foundation piles or floating structures. Standing water and surface aquifers further complicate the transport of building materials, making logistics more expensive and complex, especially in remote areas. An emblematic case is that of the Sudd Wetland, a vast swamp in the heart of South Sudan, which represents one of the greatest logistical challenges of the last decade

for humanitarian organizations. After the outbreak of the war, the combination of inaccessibility and lack of adequate infrastructure made it extremely difficult to distribute aid to isolated communities. Rivers and muddy terrain have made conventional routes impassable, preventing the use of trucks or off-road vehicles.

Flood-prone areas also present significant challenges for the construction and maintenance of infrastructure, due to the constant threat of flooding that destabilizes the ground and puts existing structures at risk. Frequent exposure to river overflows and extreme weather events makes it difficult to build a solid foundation for roads, bridges, and buildings. In these regions, water management becomes a top priority, requiring the adoption of advanced design techniques, such as embankments, drainage channels and flood protection systems. Infrastructure planning must take into account hydrological characteristics and water flow patterns, adapting structures to seasonal variables. A particularly relevant case is that of Pakistan, a country where large areas of the territory are cyclically exposed to the risk of flooding, especially during the monsoon season. This hydrogeological vulnerability represents a significant obstacle to the rise of the infrastructure level. The widespread presence of overflowing river basins, combined with the poor capacity of the soil to drain water effectively, compromises the stability of the foundations and makes it difficult to build durable infrastructure. Roads, bridges and buildings are frequently damaged or made unusable by floods, making continuous maintenance and reconstruction work necessary. The criticalities of this context manifested themselves dramatically during the 2022 flood, which hit Pakistan with unprecedented intensity, submerging about a third of the national territory. Torrential rains and the consequent overflowing of numerous rivers have isolated entire communities, making large areas inaccessible, especially in the rural regions of Sindh and Balochistan. To cope with this emergency, humanitarian organizations have had to resort to alternative means of transport, including boats, modified tractors and even air transport by military helicopters, in order to reach the completely submerged areas and deliver food, drinking water and medical supplies. The absence of viable road connections has significantly slowed down the logistical response, highlighting the fragility of existing infrastructure in the face of extreme weather events.

Added to these difficulties is that of island isolation, which introduces additional infrastructural constraints. Islands, often characterized by limited connectivity and limited space, face unique challenges in ensuring an adequate level of infrastructure. Access is frequently linked to sea or air transport, which hinders the implementation of large-scale projects and involves high costs for the procurement of materials. In particularly remote contexts, the lack of local resources imposes an almost total dependence on imports. In addition, infrastructures are subject to the effects of tropical storms, storm surges and

coastal erosion, which compromise their durability over time. The situation in Haiti clearly illustrates these problems. The island, already marked by chronic infrastructural fragility and limited connections with the outside world, has seen its criticalities worsen following the 2021 earthquake, which mainly affected the southwestern part of the country. The poor land access routes, damaged by the earthquake and obstructed by landslides and debris, have made it extremely difficult to reach the affected areas. Due to the inability to transport aid quickly by land, relief operations have had to rely on humanitarian flights and maritime transport, slowing down the distribution of basic necessities and health care. In many cases, rescue teams had to operate in conditions of almost total isolation, aggravated by the lack of energy and communication infrastructure. This event highlighted how insularity, combined with seismic vulnerability and the scarcity of logistical resources, can drastically compromise the ability to respond to emergencies and the management of infrastructures, both in the construction and reconstruction phases.

Desert areas, with their extreme conditions, pose enormous challenges to the construction and maintenance of infrastructure. Aridity, high temperatures and the enormous distances between population centers greatly complicate the planning of communication routes. Infrastructure in these regions is prone to extreme environmental phenomena, such as sandstorms, soil erosion and temperatures that can exceed 40°C. These factors make it difficult to build and maintain roads, bridges, and long-lasting facilities. Sandstorms, in particular, can quickly damage existing structures, covering roads, making tracks invisible and preventing vehicles from passing, while high temperatures accelerate the deterioration of building materials.

A significant example of how desert conditions affect the construction and management of infrastructure is **Yemen**, a predominantly desert country that faces enormous difficulties in building and maintaining stable and safe infrastructure. The territory, dominated by vast deserts and semi-arid areas, is characterized by a torrid climate and scarce vegetation, which further complicate the construction of solid structures. High temperatures and lack of water reduce the soil's ability to support large infrastructure, such as paved roads and bridges. In addition, wind and sand can quickly damage roads and cover communication routes, hindering transit and creating logistical difficulties for daily operations. The war in Yemen has further exacerbated these issues. The conflict has devastated numerous vital infrastructures, including roads, bridges, and ports, making it even more difficult to meet the challenges posed by the desert. Main roads have been destroyed or severely damaged, disrupting connections between cities and the most remote areas of the country. In a context where the construction and maintenance of infrastructure is already complex due to environmental conditions, the conflict has made access to essential goods, relief and

humanitarian assistance extremely difficult. Communication routes are often hampered not only by direct damage caused by bombing, but also by natural erosion caused by wind and sand. In many desert regions, alternative, poorly developed and unpaved roads are unable to support the heavy traffic needed for emergency operations, exacerbating the difficulty of intervening quickly in case of need. Sandstorms, which occur frequently in these areas, can quickly clear road signs and make tracks impassable. This phenomenon is combined with the already existing difficulties in managing water resources and building adequate facilities. Ports and port infrastructure, essential for the supply of food and medicines, have also been damaged or made inaccessible, further complicating the country's logistics management.

A further geographical factor that significantly affects the level of infrastructure is the location near the edges of the tectonic plates, where the seismic and volcanic risk is high and constant. These areas are subject to sudden tectonic movements, which can generate devastating earthquakes or unpredictable volcanic eruptions. Consequently, the construction of infrastructures in such contexts requires careful design and the adoption of particularly rigorous construction standards, oriented towards resilience and structural safety. The use of anti-seismic materials, expansion joints and flexible foundations is an essential condition to ensure the survival of the structures in the event of extreme events. However, even when best engineering practices are adopted, the intensity and unpredictability of natural phenomena can cause extensive damage and disrupt the operation of transport, communication and energy networks for long periods. Seismic tremors, in particular, compromise the stability of the ground, cause partial or total collapse of buildings and infrastructures, and make access to entire urban and rural areas dangerous. Added to this is the volcanic threat, which in some areas imposes further design complexity: lava flows, ash and gases emitted during an eruption can destroy roads, bridges and plants extremely quickly. This is why it is essential to accurately map the possible lava flow routes and provide exclusion or diversion zones in urban plans, especially near active volcanoes. An emblematic case that highlights the dramatic consequences of seismic vulnerability is that of the earthquake that struck Gaziantep, Turkey, in 2023. Located along the eastern Anatolian fault, an area of very high tectonic activity, the city was hit by a magnitude 7.8 quake that brought the entire infrastructure system of the region to its knees. Main roads have been destroyed or seriously damaged, preventing access to rescue vehicles and slowing down the arrival of humanitarian aid. Connections between Gaziantep and the surrounding areas have been interrupted due to the collapse of bridges and the collapse of key road arteries. The secondary roads were also impassable, blocked by landslides or made unusable by cracks in the ground. The absence of a sufficiently resilient infrastruc-

ture system has turned the emergency into a logistical crisis, leaving many communities isolated for days, without access to medical care, food or drinking water. The event in Gaziantep strongly highlighted the importance of anti-seismic infrastructures not only in the construction phase, but above all in urban planning and risk management. In seismically active territories, in fact, it is not enough to build resistant buildings: it is necessary to ensure the continuity of road connections and the functionality of logistical nodes even in critical conditions, so that rescue operations can operate quickly and effectively. Similarly, the volcanic threat requires careful planning, as areas of high volcanic activity are highly unstable for long-term infrastructure development. A significant example is Mount **Nyiragongo** in the Democratic Republic of Congo, where eruptions in 1977, 2002 and 2021 generated massive lava flows, destroying entire neighborhoods of the city of Goma and damaging vital infrastructure such as roads, bridges and plants. Mapping of lava flows and analysis of their trajectories provided crucial information to avoid the development of new infrastructure in high-risk areas. The need to adapt to these natural threats requires a sharp slowdown in infrastructure development and the constant provision of evacuation plans, often limiting the possibilities for economic and social growth. Lava flows, in fact, not only destroy infrastructure, but also make large areas inaccessible, compromising the supply of essential goods and slowing down rescue operations.

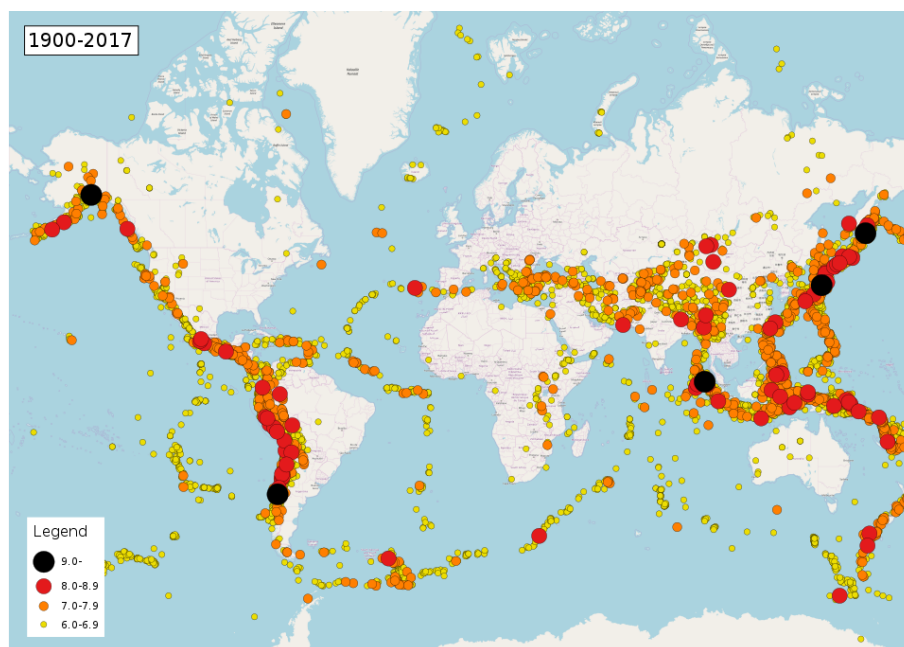


Figure 4.10: Earthquake from 1900 to 2017 [36]

In conclusion, geographical location is a crucial element in determining the possibilities for infrastructural and logistical development. From mountains to swamps, from islands

to deserts, each context poses specific challenges, in some cases aggravated by extreme natural phenomena. However, these factors do not act in isolation: the level of economic and technological development of a country plays a fundamental role in mitigating – or amplifying – these critical issues, influencing the resilience and efficiency of infrastructures and, consequently, the ability to respond in emergency situations.

### Level of development

The level of infrastructure does not depend solely on geographical difficulties, but is also a direct consequence of the level of development of a society. In territories such as Japan, Haiti and Congo, which are located in areas with high seismic or volcanic risk, it is clear how the level of development affects infrastructure capacities. Japan, with one of the most advanced economies in the world, has developed highly resilient and modern infrastructure, capable of withstanding extreme natural events such as earthquakes and volcanic eruptions. Japanese cities are designed according to the strictest anti-seismic criteria, with cutting-edge technologies that guarantee the safety and continuity of transport, communication and energy networks even in the event of disasters. On the contrary, Haiti, despite being located in an equally seismic area, has significantly more vulnerable infrastructure, due to the scarcity of resources, the lack of advanced technologies and the economic weakness of the country. Despite international efforts, the lack of proper planning and resilient structures has made it difficult for Haiti to respond promptly to disasters such as the 2010 earthquake, which devastated much of the country, destroying roads, bridges and buildings. Similarly, Congo, while also in a volcanic risk region, does not have the resources to develop modern and resilient infrastructure like Japan's. Roads, power grids and urban facilities are weak and vulnerable, and the lack of investment in advanced technologies makes it difficult to protect infrastructure from volcanic eruptions.

This comparison highlights how, although all these regions are geographically exposed to similar risks, differences in the level of development decisively influence the quality and resilience of infrastructure. In more developed countries, the presence of modern infrastructure facilitates humanitarian logistics, while in less developed regions, structural deficiencies are an obstacle to the timeliness of interventions. A key indicator for understanding a country's level of development is the Human Development Index (HDI), which divides countries into four groups:

- **First quartile – Very high human development countries** (HDI > 0.8): advanced economies with widespread and efficient infrastructures.
- **Second quartile – High human development countries** (HDI between 0.7 and

0.8): nations with good infrastructure, albeit with some structural limitations.

- **Third quartile – Countries with medium human development** (HDI between 0.5 and 0.7): states with limited infrastructure and significant logistical difficulties.
- **Fourth quartile – Low human development countries** (HDI < 0.5): countries with poor infrastructure, where emergency management is extremely complex.

Top quartile countries such as Japan (HDI 0.920), the United States (HDI 0.929), and EU countries including Italy (HDI 0.911), have highly developed infrastructure networks, which ensure efficient management of humanitarian logistics.

Europe is distinguished by an integrated transport system, which allows the rapid movement of goods and people between member states. The Trans-European Transport Network (TEN-T) is a strategic project of the European Union aimed at improving connections between different countries. For example, the Rhine-Alpine Corridor facilitates transport between North Sea ports and Italy, while the Mediterranean Corridor connects Spain, France, Italy and the Balkans, allowing for the rapid deployment of humanitarian aid in case of emergency. In addition, airports such as Frankfurt and Amsterdam serve as international hubs for logistics, facilitating the transport of materials around the world.

In the United States, logistics efficiency is ensured by a combination of advanced logistics hubs and an extensive rail network. The hubs in Memphis (FedEx), Louisville (UPS) and Chicago (North America's main railway hub) allow you to manage the transport of goods in a very short time. The U.S. rail system is the largest in the world and plays a crucial role in freight transportation, with lines dedicated exclusively to logistics connecting the country's major ports and manufacturing centers. Japan, on the other hand, stands out for the resilience of its infrastructure. The country, frequently hit by earthquakes and other natural disasters, has developed advanced emergency prevention and management systems. The Shinkansen railway network, for example, is designed to withstand earthquakes thanks to sophisticated suspension systems and automatic power cut-off in the event of seismic shocks.

In the second quartile, Iran (HDI 0.779), a country with developed but critical infrastructure, is included. Iran has an extensive railway network (about 14,000 km), which connects the main cities and ports of the Persian Gulf, such as Bandar Abbas. However, economic sanctions have limited investment in modernizing the sector, causing delays and inefficiencies. In addition, the country suffers from inadequate maintenance of road infrastructure, with many highways prone to degradation and congested traffic, especially near Tehran.

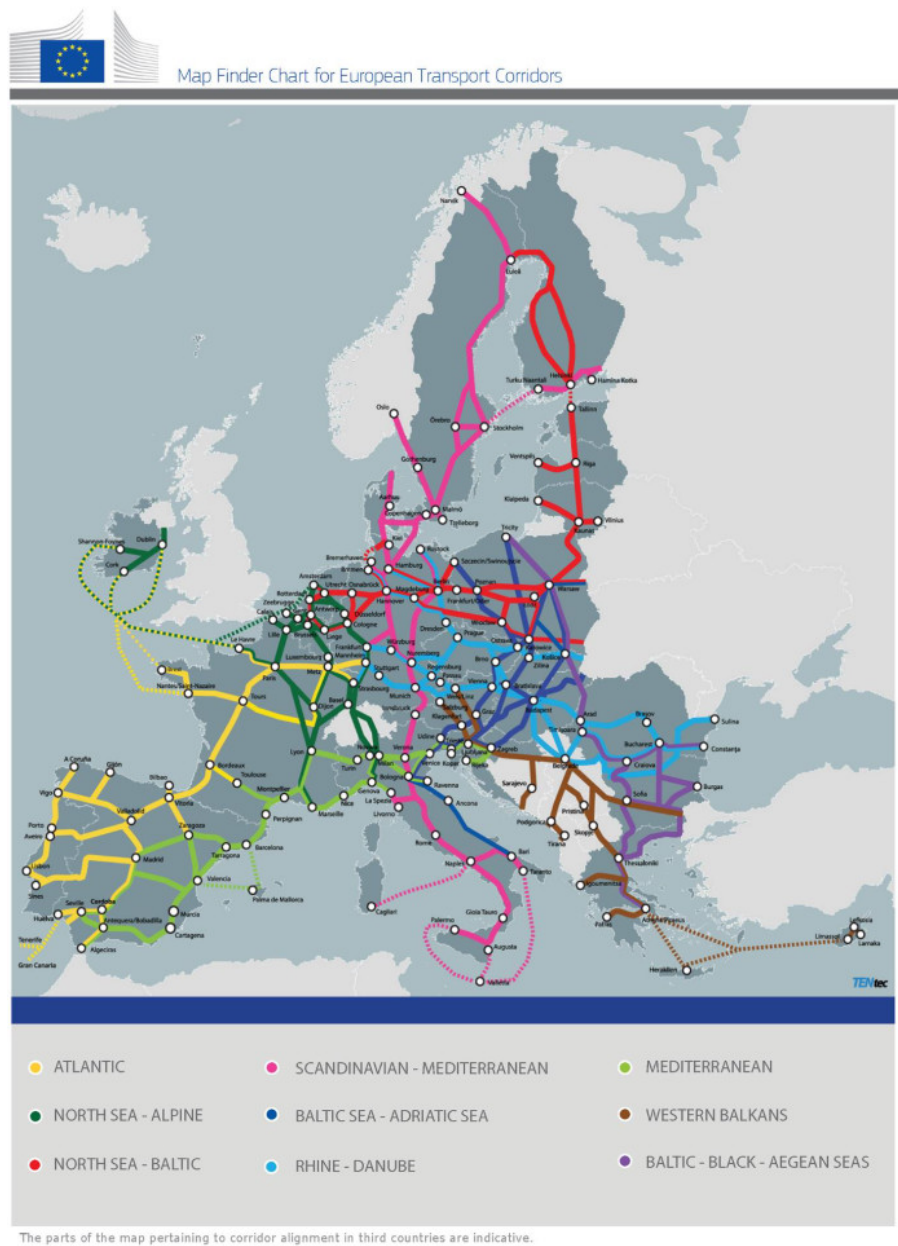


Figure 4.11: Europe Network [33]

In the third quartile, there are countries with weaker infrastructure, such as Syria (HDI 0.557) and Nepal (HDI 0.6). In Syria, more than a decade of conflict has devastated the infrastructure system: strategic bridges such as the one over the Euphrates River have been destroyed, making it difficult to transport aid to the eastern part of the country. Airports such as Aleppo and Damascus suffered significant damage, reducing their ability to receive international aid. The water and sewage system has been severely compromised, worsening the living conditions of the population. Nepal, as already highlighted, suffers from logistical problems related to its mountainous morphology. The road network is

limited, with only **15% of the roads paved** and many dirt roads becoming impassable during the monsoon season. The **rail network is almost non-existent**, with only one line connecting India. In addition, regional airports are poorly equipped, with short runways that prevent large dimensioned cargo planes from landing, which makes travel extremely complex.

In the fourth quartile, we find countries with the most poor infrastructure, such as the Democratic Republic of Congo (HDI 0.481) and South Sudan (HDI 0.381). The Democratic Republic of Congo is a vast country with an extremely limited road network: less than 10% of the roads are paved, and many of these become impassable during the rainy season. The railway network is in a state of decay, and the river ports, essential for transport along the Congo River, are often inefficient and lack modern infrastructure. The lack of rapid communication routes makes the distribution of aid extremely complex, forcing humanitarian organizations to operate with cargo flights or river transport, increasing the costs and time of intervention. South Sudan is an emblematic case of infrastructure deficiency. With only 400 km of paved roads in a vast territory, the country is almost entirely dependent on air transport for the distribution of humanitarian aid. During the rainy season, many of the unpaved airstrips become inaccessible, making it impossible to replenish food and medicine in several areas. In addition, the lack of ports and dependence on the Nile for inland transport further exacerbate the country's logistical vulnerability.

Therefore, it is clear that the level of development of a country is closely linked to the quality of its infrastructure and the ability to respond to emergencies. In the countries of the first quartile, an advanced logistics system allows for rapid and effective intervention. Conversely, in countries with low HDI, the scarcity of adequate infrastructure slows down the distribution of aid, increasing the risk of prolonged humanitarian crises. Investing in infrastructure development in these regions would improve emergency response capacity and foster sustainable economic growth in the long term.

## Event Typology

In the context of humanitarian emergencies, the type of triggering event plays a decisive role in defining the degree of accessibility to logistical infrastructures, both in the phase immediately following the event and in the medium-long term. The nature of the event, which can be sudden or gradual, localized or widespread, short or long-term, directly affects the ability of humanitarian organizations to reach affected populations, distribute essential aid and ensure operational continuity in relief and reconstruction activities.

It is useful to distinguish between short, high-intensity destructive events, such as earth-

quakes, volcanic eruptions, and tornadoes, and protracted events, such as armed conflicts and persistent floods. Fires are located in an intermediate zone: they can have variable duration and different impacts depending on the geographical context and the readiness of the containment intervention. Events such as earthquakes or tornadoes, although very short-lived, can cause devastating structural damage to road networks, bridges, airports, ports and electricity and telecommunications networks. In these cases, physical access to the affected areas can be completely blocked, making it necessary to use alternative modes of transport (helicopters, drones, convoys on secondary roads) or the use of temporary logistical bases set up on the edge of the impact zone. In the case of volcanic eruptions, in addition to material destruction, the problem of accessibility is amplified by the presence of ash and harmful gases, which compromise the safety of transport and rescuers. Floods, on the other hand, often cause more distributed and less explosive, but long-lasting damage: submerged or collapsed roads and bridges, territories made impassable and long restoration times make it difficult for goods and people to move for weeks or months. Finally, armed conflicts represent a particularly complex case: accessibility is not only determined by the physical condition of the infrastructure, but also by the security of the area, the presence of hostile actors and the control of the territory. This generates a condition of chronic instability, in which access can be guaranteed one day and completely forbidden the next, requiring flexible, redundant and highly internationally coordinated logistical solutions.

The following table summarizes the impact of the different events on accessibility in terms of duration and initial and prolonged severity:

Event Type	Duration	Initial impact	Impact over time
Earthquake	Brief	Very high	Decreasing
Volcanic eruption	Short/Medium	Elevated	Locally persistent
Flood	Medium/Long	Elevated	Persistent
Fire	Short/Medium	Medium	Localized
War	Long	Variable	Highly unstable
Tornado	Brief	Very high	Decreasing

Table 4.13: Accessibility Duration Impact

In addition to the type of event, a further strategic factor in the planning of logistical operations is represented by the degree of predictability and predictability of the event itself. Predictability refers to the ability to identify geographical areas or periods in which a certain type of event is statistically more likely, while predictability refers to the

possibility of precisely identifying when, where and with what intensity the event will occur.

Event	Predictability	Predictability	Relevant factors
Earthquake	High	Low	Seismic zone, geological history
Eruption	High	Low/Medium	Seismic activity, volcano monitoring
Flood	High	Average	Seasonality, topography, recent rainfall
Fire	Average	Low/Medium	Dry climate, human activity, environmental monitoring
War	Medium/High	Low	Political tensions, regional dynamics
Tornado	High	High	Local climate, season, early warning systems

Table 4.14: Event Predictability

A concrete example of a predictable and predictable event is Hurricane Harvey (August 2017), which hit Texas causing extensive flooding and severe infrastructure damage. Thanks to weather models and early warning systems, it was possible to accurately predict its path, timing and scope. This allowed for the early activation of evacuation plans and the preventive positioning of logistical resources, improving the readiness of the humanitarian response. On the other hand, the Gaziantep earthquake occurred in Turkey in February 2023. This is a predictable but unpredictable event: the region of eastern Anatolia is in fact known for its high seismic activity and has long been under observation by the scientific community. However, the event occurred without specific warning, preventing any immediate preventive action and dramatically affecting the local population and infrastructure. The logistical reaction therefore had to be completely activated in an emergency, with considerable initial delays also linked to the inaccessibility of several affected areas.

The type of event therefore represents a key variable in the design and management of

humanitarian supply chains. It affects the severity of the infrastructural damage, the timing of the response, the possibility of preventive planning and the effectiveness of the intervention. An in-depth understanding of the nature of the event in terms of duration, intensity, predictability and predictability allows humanitarian organizations to adopt more robust and targeted logistical strategies, reducing response times and maximizing the effectiveness of the aid distributed.

### Climatic factors

Accessibility to infrastructure does not depend exclusively on the level of development or quality of the same, but is also strongly influenced by climatic factors that can prevent or limit access. Rising global temperatures and climate change have led to an increase in extreme weather events, such as floods, storms, cyclones, heavy snowfall, and forest fires. These phenomena, which are increasingly frequent and intense, seriously damage transport networks, block roads and make entire areas inaccessible, hindering not only the mobility of people, but also the supply of essential goods and emergency relief.

A case in point is the earthquake that struck Nepal in 2015. The logistical challenge for humanitarian organizations was immediate and complex: many roads were destroyed or obstructed by landslides, and several mountain villages were completely isolated. As if that were not enough, a few weeks after the earthquake the monsoon season began, with torrential rainfall that made access to the affected areas even more difficult. During the monsoon, landslides and landslides increased, further damaging the dirt roads and mountain paths that connected the most remote towns. In many areas, the helicopter was the only means of transportation, but even these vehicles were hampered by adverse weather conditions: dense fog, heavy rain, and high winds limited operating windows for flight, causing mission delays and leaving some communities isolated for days, if not weeks. In addition, goods from abroad bound for the capital Kathmandu suffered major delays due to the unsuitable conditions for safe take-off or landing.

A second significant case is that of Mozambique in 2019, hit by Cyclone Idai, one of the most devastating ever recorded in the southern hemisphere. Again, the humanitarian response was hampered by climatic factors: widespread flooding turned entire areas into impassable swamps, destroyed bridges and rendered many roads unusable. The rescue teams were forced to resort to boats, helicopters or long alternative routes to reach the affected towns. The few logistics warehouses available were also damaged, making it necessary to create temporary hubs in emergency conditions.

Alongside events related to tropical rains and cyclones, an equally critical impact is rep-

resented by extreme cold, which can paralyze distribution networks in mountainous or high-altitude areas. A recent example is the humanitarian crisis faced in Afghanistan during the winter of 2022–2023. Following the collapse of the government and the economic crisis, millions of Afghans were living in extremely vulnerable conditions. The arrival of a very harsh winter season, with temperatures dropping to  $-33\text{ }^{\circ}\text{C}$  in some regions and exceptional snowfall, has made entire provinces of the country inaccessible, particularly in central and northern regions such as Bamiyan and Ghor.

The already fragile mountain roads were blocked by snow, and humanitarian convoys could not reach many isolated villages. NGOs such as WFP and IRC found themselves forced to postpone missions, divert routes or, in some cases, resort to pack animals and air transport, but with very limited resources. This climate isolation caused hundreds of deaths and prevented the timely supply of essential goods such as fuel, medicines, and food.

Fires can also significantly limit accessibility to infrastructure, as demonstrated by Canada in 2023, during the most devastating fire season in its history. The fires damaged critical infrastructure, including telephone lines and fiber optics, disrupting communications between cities and slowing rescue operations. Roads, some of which were destroyed by fire, became impassable, and alternative routes were blocked by rubble or obstacles caused by dense smoke and reduced visibility. Air vehicles, crucial for rescue operations, were also limited by adverse weather conditions, including thick smoke that reduced visibility and high temperatures that hindered operations. These difficulties prevented the timely arrival of aid, leaving many vulnerable communities without vital resources for days.

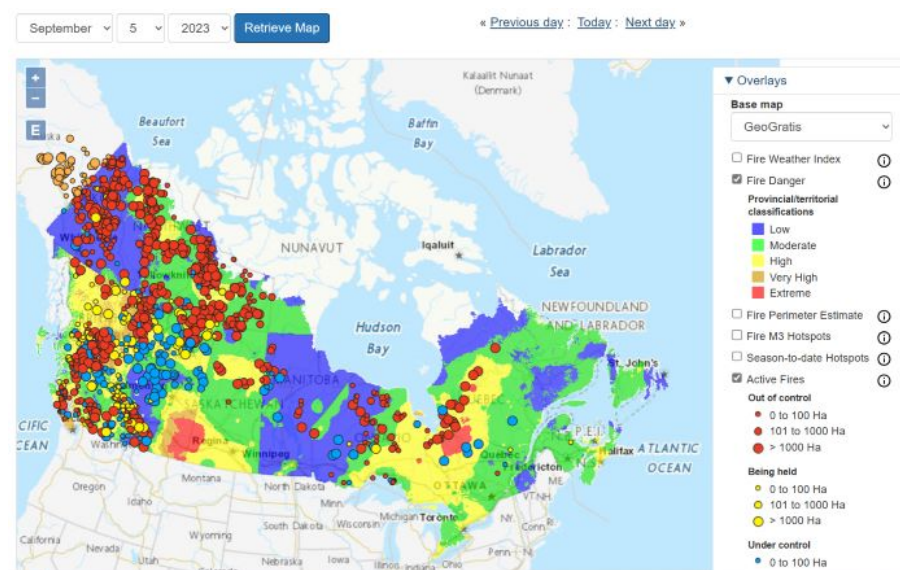


Figure 4.12: Canada Wildfires 2023 [4]

These examples, placed in distinct geographical and climatic contexts, highlight how climate is a crucial element in the design and management of humanitarian supply chains. Transport infrastructure can become inaccessible due to extreme weather phenomena, such as heavy rains, cyclones, cold spells and snowfall, compromising the effectiveness of even the most accurate logistics plans if not complemented by robust resilience strategies. It is therefore essential to adopt flexible and proactive solutions, such as the provision of stocks in decentralized hubs, the diversification of means of transport, the use of climate monitoring technologies and the adoption of forecasting models that integrate environmental variables. Only through an adaptive logistical approach will it be possible to ensure an effective humanitarian response even in the most climatically vulnerable contexts.

### Political factors

In many situations, accessibility to infrastructure depends not only on climatic factors or the level of infrastructure, but also on political decisions, armed conflicts, or authoritarian regimes that can limit or hinder the free flow of goods and services. Political choices, government strategies and war dynamics profoundly influence a country's ability to guarantee the operation of its infrastructure networks, resulting in artificial barriers that, although not derived from natural events, can have equally devastating consequences. Unlike physical obstacles, which are often temporary, human barriers can be long-lasting, precluding access to vital resources for entire populations. In particular, armed conflicts and political decisions, sometimes motivated by ideological or economic considerations, can impede access to critical infrastructure, such as transport, communication and distribution of humanitarian aid, creating enormous difficulties for organisations working on the ground.

As mentioned above, the wars in Yemen and South Sudan have had a devastating impact on infrastructure, hindering access to the most vulnerable areas. In both contexts, conflicts have caused the destruction of roads, bridges and hospitals, preventing relief operations and hindering the flow of humanitarian aid. Communication routes have been damaged or completely cut off, while the occupation of strategic territories has further complicated the logistics of aid, with many areas remaining inaccessible due to the presence of fighting, banditry or mines. These human obstacles, more than the physical hardships associated with natural disasters, have made it extremely difficult for humanitarian organizations to provide timely assistance to populations, exacerbating the humanitarian crisis in both nations.

A similar impact was also had with the Kivu conflict in the Democratic Republic of Congo (DRC). For decades, the Kivu region has been the scene of armed conflicts between rebel groups and government forces, with a devastating impact on access to infrastructure.

Transport routes, both by land and by river, are constantly threatened by armed attacks, banditry and militarization of the territory. The many destroyed roads and bridges have made it difficult for humanitarian organizations to reach vulnerable populations. In addition, the conflict has generated a large movement of refugees and displaced persons, further complicating aid logistics, creating territorial barriers and inaccessible areas. Continued political and military instability has made it difficult to coordinate humanitarian operations, with territory control changing frequently, preventing the safe passage of goods and people.

Even during the Russian-Ukrainian conflict, there has been a major limitation on the accessibility of infrastructure, which has had devastating repercussions on humanitarian operations. The physical destruction of crucial infrastructure such as bridges, roads and railways has reduced the ability to connect the worst-hit regions, isolating entire communities. In particular, the demolition of the Antonivskyi Bridge over the Dnipro River blocked one of the main communication arteries, hindering the transport of essential goods to besieged areas.

The closure of access routes has forced humanitarian organizations to look for alternative, longer and more dangerous routes, significantly slowing down the distribution of aid. In addition, the occupation of strategic territories and the blockade of humanitarian corridors have prevented the smooth flow of vital resources. Even during so-called "windows of peace" or temporary ceasefires, forces on the ground have sometimes deliberately blocked access to conflict zones, making it difficult for humanitarian organizations to enter. Checkpoints, ongoing clashes and the increasing militarization of the streets have reduced the possibilities of movement, putting the safety of operators at risk and slowing down the delivery of food, medicine and other necessities. The continued instability has also complicated the logistical coordination of operations, further hampering the speed and effectiveness of rescue. The destruction of infrastructure and the difficulty of access have therefore aggravated the suffering of the civilian population, preventing humanitarian agencies from adequately responding to urgent needs.

These examples show how human factors, such as armed conflict, political decisions, and power dynamics, can heavily affect infrastructure accessibility. Unlike natural obstacles, which are usually temporary, the barriers created by political and military dynamics can last for years, making it difficult not only to access critical resources, but also to deliver humanitarian aid in a timely manner. The organizations involved face not only the physical difficulties of transportation and logistics, but also political complications and legal barriers, which require much more complex strategic planning. Responses to these challenges must be particularly flexible and ready to adapt to an ever-changing

environment, seeking solutions that can guarantee access to vulnerable populations, even in extremely difficult conditions.

### 4.4.3. Level of Cooperation

As mentioned in the introduction of the chapter, the ability to effectively receive humanitarian aid depends not only on the accessibility of logistical infrastructure, but also on the level of cooperation and interaction with the local population. In this context, language, religious and educational barriers can pose significant obstacles, profoundly affecting the ability to cooperate between relief organizations and affected communities. Although the inaccessibility to infrastructure is immediately visible, these less tangible socio-cultural factors often substantially complicate aid management, resource distribution and communication between stakeholders. Effective communication is essential for the success of operations, but when linguistic and religious differences come into play, or when the population has a low level of education, misunderstandings and mistrust can arise that hinder or delay humanitarian intervention. Overcoming these barriers requires intensive awareness-raising, training and adaptation work on the part of operators in the field, who must find effective ways to foster cooperation and active involvement of the local community.

### Language

Language barriers are one of the most obvious obstacles in humanitarian operations, as language is the fundamental tool for communication, the distribution of aid and the dissemination of vital information. When local languages are different from those spoken by humanitarian workers, misunderstandings can emerge that compromise the quality and timeliness of responses. In conflict or disaster contexts, where clarity and precision are essential, mutual understanding is crucial to avoid unnecessary delays and dangers to the health of those involved. In Syria, for example, the diversity of regional dialects and languages has made it difficult for humanitarian personnel to communicate with local populations, sometimes leading to misunderstandings about how aid is distributed or what health practices should be followed. Translation and interpretation are essential, but not always sufficient to overcome language challenges. Local languages, in fact, often differ even in dialectal variants, creating an additional level of complexity. When the language is not properly understood, supporting communications can not come in the right way, increasing the risk of errors. In addition, the lack of language skills among humanitarian personnel can slow down the ability to adapt to urgent needs and coordinate operations efficiently.

In such contexts, it is crucial for humanitarian organizations to recruit local interpreters or train their staff in regional languages, not only to facilitate verbal communication, but also to understand the cultural and social values that could influence the community's reactions to the aid provided. Continuous training of interpreters and facilitators who have a deep understanding of local language variants is a vital strategy to improve communication and to ensure that aid is distributed as fairly as possible. Organizations must be prepared to invest in this aspect, so that language barriers do not become an insurmountable obstacle to rescue operations.

## Religion

Religious beliefs can represent particularly complex obstacles in humanitarian operations, especially in contexts where faith is not only a personal dimension, but a structural element of collective identity and social dynamics. In many crisis areas, religious differences not only influence the willingness of local communities to accept aid, but also affect the ways in which aid is distributed, received and sometimes even refused. Humanitarian organizations thus find themselves operating in environments where their presence can be read not in terms of neutrality, but as an ideological or cultural stance, depending on the religious matrix attributed to them by local groups. In these situations, the strong religious identity of some communities has generated resistance to external help, fueled by distrust of everything that is perceived as "other", especially if associated with different religions or cultures. In some cases, humanitarian organizations have been accused of proselytizing or wanting to interfere with the local religious order, thus finding themselves hindered or excluded from the areas most in need. Even where entry was possible, cooperation with the local population was difficult, with real risks of boycott, misunderstandings and internal tensions.

A relevant example is Afghanistan, where the historical division between Sunnis and Shiites has strongly influenced the effectiveness of humanitarian interventions, particularly after the withdrawal of international forces in 2021. In several regions of the country, especially rural regions or under the control of local authorities linked to radical religious movements, there have been episodes in which entire communities have been excluded from aid on the basis of their religious affiliation. The case of the Hazaras, a historically persecuted Shiite minority, is emblematic: numerous testimonies indicate how in some areas this population has been systematically ignored or marginalized by aid distribution processes, increasing their vulnerability and worsening their already precarious living conditions.

To address these challenges, it is essential that humanitarian organizations adopt cultur-

ally sensitive strategies, capable of respecting the religious codes of the territory without compromising the principles of neutrality, impartiality and universality. An effective approach involves the involvement of local religious leaders, who can act as guarantors of equity in the distribution of aid and facilitate dialogue with communities. In addition, the use of cultural and religious mediators, possibly belonging to the same area or faith as the assisted population, has proved essential to reduce tensions, overcome mistrust and build collaborative relationships. Ultimately, religious barriers are not just logistical or organizational obstacles: they are issues of legitimacy, trust, and recognition. Ignoring them means risking making even the most technically well-structured intervention ineffective. Addressing them proactively, on the other hand, can turn a potential source of conflict into a resource for building bridges between responders and affected populations.

## Education

Educational difficulties can severely limit communities' ability to respond to emergency situations effectively, making them more vulnerable to the effects of natural disasters or conflict. In many developing countries, access to education is fragmented or absent at all, and this is directly reflected in the resilience of local populations. Without an adequate knowledge base, those affected struggle to correctly interpret warning signs, understand instructions from humanitarian workers or engage in self-protective behaviour. This results in a slower, disorganized and less effective response, which compromises both survival in the short term and the ability to rebuild in the long term.

An emblematic case occurred in South Sudan during the floods of 2020, when large areas of the country were submerged by water, affecting millions of people. In many of the most isolated rural areas, the level of education was extremely low, and the population did not have the basic information to deal with an emergency of this magnitude. A lack of knowledge of the health risks associated with floods, such as contamination of drinking water, the proliferation of malaria-carrying mosquitoes or the transmission of gastrointestinal diseases, has exacerbated the crisis. The communities, often illiterate or poorly informed, were unable to follow health guidelines, nor to implement simple preventive measures such as boiling water or building latrines far from wells. Illiteracy is a particularly critical barrier. The inability to read and understand written communications drastically limits the effectiveness of the transmission of vital information, such as evacuation instructions, health procedures, or logistical indications of aid distribution points. In many cases, flyers, information signs or public notices prove useless for a large part of the population, forcing operators to resort to alternative tools such as illustrations, practical demonstrations or messages transmitted orally. The difficulty in filling out registration

forms or in the light list of beneficiaries can also unknowingly exclude illiterate people from accessing aid, further exacerbating marginalisation. Illiteracy, therefore, not only hinders immediate communication in emergency situations, but also fuels the spread of unfounded rumors and misinformation, as the population relies exclusively on informal sources of communication, which are often unreliable.

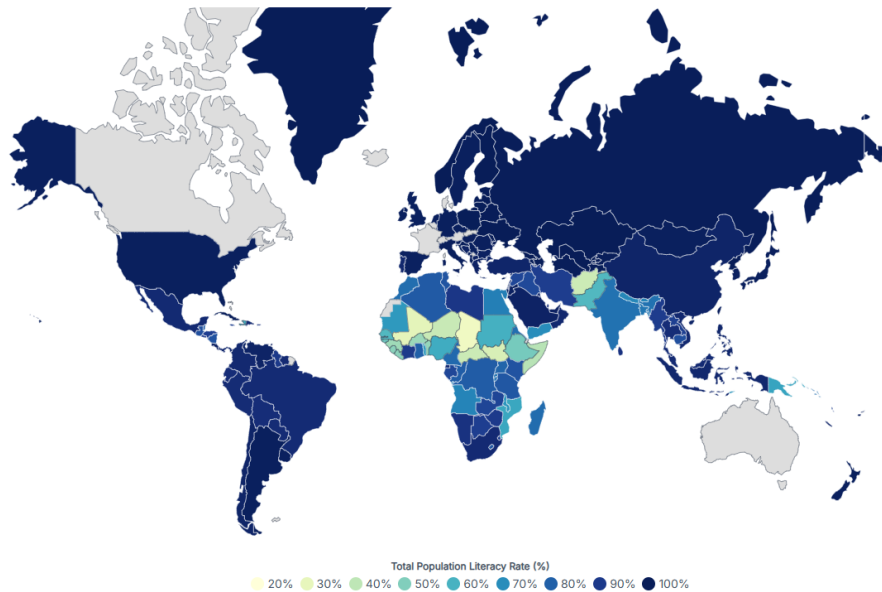


Figure 4.13: Literacy Rate by Country 2025 [39]

In contexts like this, the lack of education is not only about understanding the messages conveyed, but also about the ability to actively participate in the decision-making process. Poorly educated populations tend to be excluded from dialogue with humanitarian organisations, contributing to passivity and dependence on external aid. In addition, the absence of education is often accompanied by a lack of trust in institutions or authorities, and can reinforce erroneous beliefs or entrenched superstitions, which further hinder response strategies. In some African communities, for example, the origin of the disaster can be attributed to divine punishments, evil spirits or curses, leading people to refuse modern medical care or to distrust recommended hygiene practices. In other cases, unfounded rumors may spread about the effectiveness or danger of aid, such as the idea that vaccines cause infertility or that the food distributed is contaminated. These beliefs, often transmitted orally and reinforced by strong community cohesion, can prevent a rapid and effective response, creating a climate of suspicion that further isolates affected populations. To address these challenges, humanitarian organizations must invest in short- and long-term educational programs that go beyond material assistance. It is essential to promote awareness-raising activities on environmental and health risks, encourage the

dissemination of basic hygiene practices, and introduce simple and visual tools to convey vital information even to those who cannot read or write. Working with schools, community leaders, and local health facilities can help create an educational network that reaches the entire population, even in the most remote areas. In parallel, the training of local volunteers, who can act as a bridge between the community and humanitarian workers, is a winning strategy to consolidate awareness and response capacity at the local level. Educational barriers, therefore, must not be seen only as a problem to be solved immediately, but as a structural challenge to be faced with strategic vision and continuity over time. Improving literacy, countering disinformation and debunking ingrained myths or superstitions through patient and culturally sensitive work is one of the fundamental keys to making communities more autonomous, informed and resilient in the face of future humanitarian crises.

Overcoming language, religious and educational barriers is essential to ensure the success of humanitarian operations. Organizations must adopt a strategic approach that goes beyond simply distributing aid, aiming to build lasting and respectful relationships with local communities. It is crucial that humanitarian organizations work to understand the different cultural and social dynamics, and that they develop adaptive capacities to respond appropriately to the specific needs of each community. Hiring local staff, building support networks involving community and religious leaders, and investing in lifelong learning for humanitarian personnel are all measures that help overcome socio-cultural barriers.

Only with a sensitive and inclusive approach can organizations ensure that aid reaches those who need it most, without discrimination and without creating further social fractures. In addition, it is crucial that communities are actively involved in the planning and execution of interventions, to ensure that solutions are sustainable in the long term. Respect for cultural and religious differences, together with continuous training in educational practices, can not only improve the effectiveness of humanitarian operations, but also contribute to building greater resilience in vulnerable communities.

#### 4.4.4. Internal Factors

While external factors influence the ability to receive aid during a given humanitarian crisis, internal factors affect the ability of a specific NGO to provide humanitarian assistance. These factors also need to be analysed in detail, as the ability to distribute aid depends not only on a country's ability to receive it, but also on the ability of organisations to deliver it. In the following paragraphs, all the main internal factors will be illustrated and

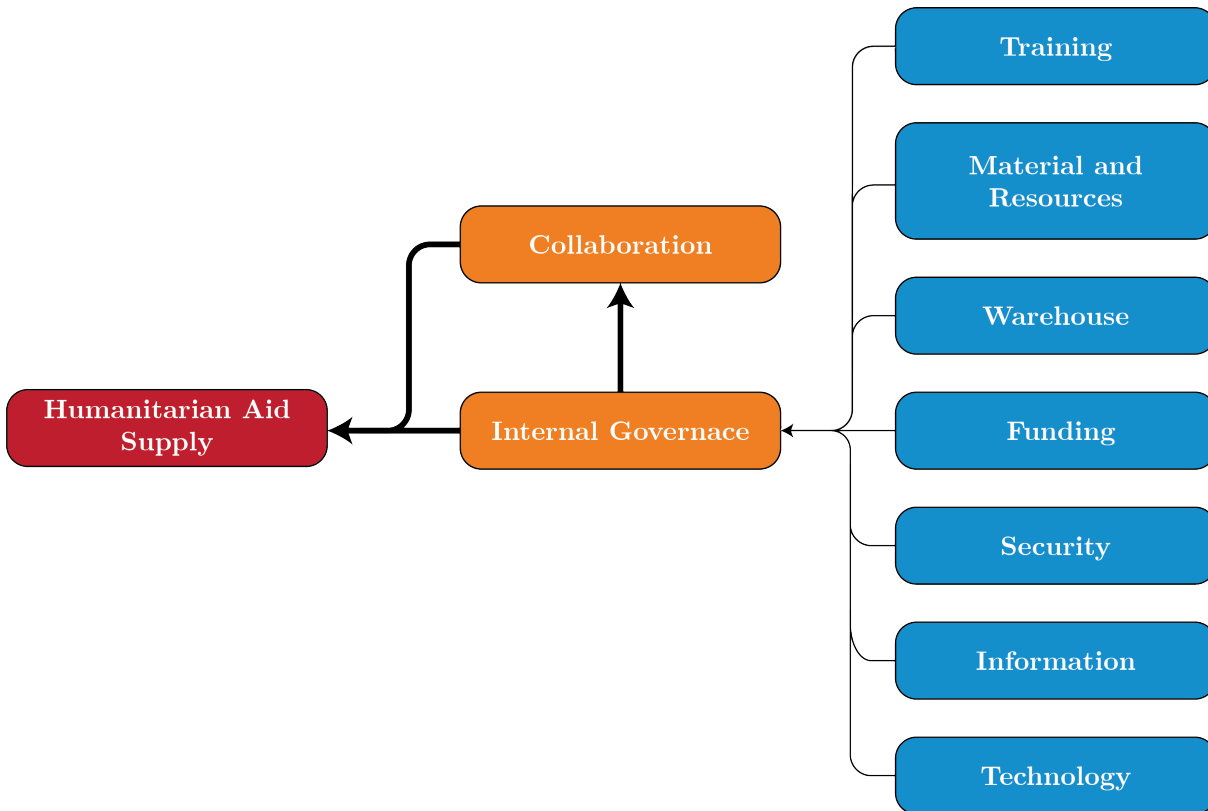


Figure 4.14: Internal Factors

deepened; however, before proceeding, it is necessary to carry out a preliminary analysis of the relationships between these factors and how they affect an NGO's ability to provide humanitarian assistance.

#### 4.4.5. Internal Governance and Collaboration

As shown in Figure fig. 4.14, internal governance and collaboration with other entities are closely interconnected. More precisely, the ability to collaborate effectively with other organizations depends to a large extent on the quality of internal governance. Although this concept may seem intuitive, the graph highlights some fundamental aspects: first of all, good internal governance is a necessary, but not sufficient, condition for establishing effective collaborations with other entities. In fact, even with optimal internal management, an NGO could face difficulties in external cooperation due to the organizational methods of the other actors involved.

Internal governance involves having a clear organizational structure, efficient internal communications, well-defined decision-making processes, and optimal management of available resources. These elements not only help achieve internal goals, but also lay the

foundation for effective and sustainable external collaboration. An NGO that manages to guarantee solid internal governance is able to present itself as a reliable and competent partner, thus increasing the chances of establishing profitable alliances. On the other hand, collaboration with other entities is not only dependent on internal capabilities, but also on the availability, operational strategies and objectives of the partner organisations. Divergences in approaches, response times or resource management can hinder the creation of effective synergies, regardless of the internal strength of the individual NGO, but these aspects will not be addressed in this discussion.

Finally, it is important to underline that the factors that influence the internal organization, **Training, Material and Resources, Technology, Warehouse, Funding, Security, Information** are the same as those that influence collaboration with other entities and therefore are the fundamental factors regarding the possibility of providing aid.

## Cooperation

Cross-agency collaboration is one of the central elements in an NGO's ability to provide effective and timely humanitarian assistance during an emergency. In an extremely complex and dynamic operational context such as that of humanitarian crises, no organization, no matter how large or prepared, is able to manage all the needs that emerge on its own. Collaboration between NGOs, international agencies, local governments, private entities and other civil society entities is therefore an essential strategic imperative to ensure a coordinated and efficient response. This collaboration is mainly declined in three fundamental forms: **operational coordination, sharing of resources** and mutual support in **information management**. Operational coordination makes it possible to avoid duplication of efforts, reduce response times and maximize the effectiveness of interventions. By creating common planning and data exchange platforms, the responsiveness of humanitarian operations can be significantly improved. The sharing of resources – such as means of transport, warehouses, logistics facilities, expert personnel and technological tools – makes it possible to optimize the use of available logistics capacities, reducing costs and increasing territorial coverage. Finally, mutual support in information management promotes better planning of activities, allowing you to adapt quickly to changes in the operating environment.

The degree of effectiveness of collaboration depends strictly on the quality of the internal governance of each NGO. Clear organizational structures, rapid decision-making processes, fluid internal and external communications are fundamental prerequisites for establishing functional synergies with other entities. However, organisational culture also

plays a key role: NGOs that promote transparency, trust, respect for diversity and flexibility in external relations are more easily integrated into multilateral response systems. In addition, the ability to adapt quickly to the changing needs of other partners and to maintain a pragmatic approach is essential. Numerous case studies analyzed confirm how



Figure 4.15: WFP Operators [37]

collaboration was decisive for the success of the interventions. For example, in the 2015 earthquake in Nepal, the Logistic Cluster coordinated by WFP enabled the integrated management of the logistical flows of dozens of NGOs, optimising the use of the limited infrastructure available and facilitating the reach of isolated communities. NGOs, working jointly with the local population, have implemented innovative solutions such as the use of pack animals to overcome difficulties in accessing mountain areas, demonstrating how direct community involvement is an effectiveness multiplier. The timely activation of a network of regional logistics hubs, in collaboration with the Nepalese government, has made it possible to drastically reduce the delivery time of aid in the most remote areas.

Similarly, during the crisis in Ukraine since 2022, cooperation between the Logistic Cluster, the IRC, Atlas Logistique-HI and other organizations has made it possible to overcome difficulties related to the destruction of infrastructure, fuel shortages and the closure of airspace. Cross-border logistics hubs were quickly established in Poland and Romania, which served as bases for the coordination of humanitarian convoys. In a context characterized by high security risks, the continuous updating of logistical information and operational flexibility have made it possible to keep vital humanitarian corridors open. In addition, a close collaboration was developed with the private sector, which ensured

support for the transport, storage and distribution of critical healthcare supplies, including through the use of digital platforms for real-time tracking. Other significant examples include the response to Hurricane Harvey in the United States, where FEMA coordinated an extensive network of public and private agencies, managing to ensure a widespread distribution of aid despite severe infrastructure difficulties. The creation of a national emergency operations centre and the use of advanced technologies for monitoring climate events have fostered a rapid mobilisation of resources. Also in Pakistan, during the 2022 floods, the network of Humanitarian Response Facilities jointly created by WFP and the Government of Pakistan enabled a more widespread and efficient logistical response, despite the challenges posed by the size of the affected area and the widespread destruction of road infrastructure.

Importantly, despite the benefits, cross-agency collaboration also comes with some significant challenges. Differences in operational mandates, organizational models, administrative procedures, and cultural approaches can create friction and slowdowns. Some agencies may have priority visibility needs, while others may be focused solely on speed of response. Effective management of these aspects requires specific negotiation skills, intercultural adaptability and advanced techniques for managing multilateral alliances. In particular, it is essential to define clear collaboration protocols, shared priority criteria and dispute resolution mechanisms upstream. A further element to consider is the growing role of public-private partnerships: collaboration between NGOs and private companies has proven to offer considerable added value, providing technological resources, logistical expertise and distribution networks that, if well integrated, can accelerate and improve the impact of humanitarian operations.

## Internal Governance

Internal governance is one of the central pillars in an NGO's ability to provide effective humanitarian assistance during a crisis. It includes the set of organizational, communicative and decision-making mechanisms that ensure the harmonious functioning of the different components of the organization. As highlighted in the analysis model fig. 4.14, internal governance is not only an autonomous element, but acts as a pivot that directly connects and influences other critical factors such as staff training (**Training**), availability of materials and resources (**Material and Resources**), technological level (**Technology**), warehouse management (**Warehouse**), availability of funds (**Funding**), security of operations (**Security**) and the flow of information (**Information**). Effective management of these aspects is vital to ensure organizational cohesion and operational readiness. Effective internal governance ensures that these operational areas interact in

a fluid and synergistic way. An organization that is able to implement clear decision-making processes, a rapid and efficient flow of information and a balanced distribution of resources is able to respond more promptly and effectively to crisis situations. Without a well-structured internal system, the use of technology to track aid or optimize logistical routes would be ineffective; the lack of adequate internal coordination would risk slowing down the intervention, aggravating the situation of the affected populations. In addition, poor human resource management would compromise the quality of operational training, weakening the readiness and responsiveness of the organization. Internal governance is not limited to an administrative function, but directly affects the operational capabilities of the entity. In fact, the creation of interdisciplinary teams, the clear assignment of roles, the planning of tasks and the management of feedback are practices that strengthen the resilience of the organization. This systemic approach makes it possible to deal with complex situations in the best possible way, while maintaining consistency between strategic and operational objectives.

Analyzing some of the NGOs involved in the study, concrete examples emerge of how different organizational models of internal governance influence operational efficiency.

- **WFP** adopts a highly centralised model: headquarters provides precise guidelines to all its operational units on the ground. This approach ensures consistency in procedures and rigorous resource management, reducing the risk of inefficiencies or overlaps. However, it requires a high capacity for rapid vertical communication, especially during emergencies.
- **IFRC** uses a more decentralized structure. Although there are shared global standards, individual national societies have considerable decision-making autonomy. This allows for a response that is highly adapted to the local context, but also requires solid internal coordination mechanisms between the different levels of the organization.
- **MSF** bases its internal governance on a semi-autonomous operating cell system. The various Operational Centers (e.g. Brussels, Amsterdam, Geneva) have wide margins of autonomy in the management of missions, but share common principles of intervention and support tools such as logistical platforms and information systems.
- **DR** adopts a highly streamlined and technologically advanced management: internal governance is facilitated by a strong digitization of logistics and information flows, which allows rapid decision-making and complete traceability of activities, even with a relatively small operational staff.

- **ActionAid** integrates internal governance with a strong involvement of local communities, making sure that the planning and execution of activities are informed directly by the needs of the beneficiaries. This model requires internal management that is particularly attentive to coordination between central and local offices.
- **Emergency** is characterized by a highly vertical structure, where each project is directly controlled by the headquarters in Italy. This model allows very high quality standards, especially in the healthcare sector, but makes flexibility in the field more limited than other models.

All these examples highlight how internal governance, if well designed and managed, constitutes a critical competitive advantage for humanitarian NGOs. The ability to integrate information, resources and decisions quickly and consistently determines to a large extent the effectiveness of humanitarian operations. In the following paragraphs, the individual factors that, through internal governance, influence the operational capacity of NGOs will be explored.

## Training

Training is a key element that directly affects the operational capacity of an NGO in the management of humanitarian emergencies. The readiness with which an organization is able to respond to natural disasters or humanitarian crises is closely linked to the level of preparedness of its operators. Although many organizations already invest significant resources in staff training, the extremely varied operational context and the strong presence of volunteers, often with very different backgrounds, make it difficult to ensure a homogeneous level of preparation among all operators in the field. Those participating in humanitarian missions do not always have specific training or consolidated technical experience, which can affect the speed and effectiveness of the response in critical situations, increasing the risk of operational inefficiencies. It should be emphasized, however, that in modern NGOs, training is now a consolidated and structured component of operational activities. The training courses are divided into several levels to meet different operational needs: on the one hand, practical courses are provided for fundamental operational roles such as forklift drivers, drivers, electricians and logistics workers. These courses aim to provide immediate practical skills, which are critical for the day-to-day logistical support of field operations. On the other hand, specialized courses of advanced level are offered, which include training in first aid, personal safety management, inter-organizational coordination, emergency leadership, management of sensitive information and the use of advanced logistics technologies.

The case of the 2015 Nepal earthquake highlights how crucial training is. In a context of destroyed infrastructure and limited access, the ability of NGOs to quickly adapt their logistical protocols – for example by organising transport via pack animals or using alternative locally mapped routes – has only been made possible thanks to staff who are properly trained to operate in extremely hostile environments. Similarly, during the 2022 crisis in Ukraine, managing healthcare logistics in war conditions and cold temperatures required highly specialized skills that only advanced training programs could provide. The ability to organize safe humanitarian corridors and adapt the supply chain in response to rapidly deteriorating local conditions was also closely related to the level of training of personnel in the field.



Figure 4.16: LC training session [24]

Another significant example concerns the management of floods in Pakistan in 2022, where the use of alternative means of transport such as modified boats and tractors was made possible by the targeted training of logistics staff. Again, the ability to find creative and effective solutions was the direct result of adequate training, oriented towards problem-solving and operational adaptability.

Finally, it is important to emphasize that training is not an isolated event, but an ongoing process. Humanitarian scenarios evolve rapidly and new skills become necessary – such as supply chain management through digital platforms, the use of real-time tracking technologies, coordination with private partners, management of sensitive information and planning complex multimodal operations. For this reason, the most effective NGOs invest not only in the initial training of staff, but also in constant updating, the creation of internal knowledge hubs, the development of mentoring programs and the promotion of networks for the exchange of best practices. Only a systemic and continuous approach to training can guarantee a truly timely, effective and resilient humanitarian response in

the face of events of increasing complexity.

## Material and Resources

Effective management of materials and resources is one of the most critical aspects for the success of an NGO's operations during a humanitarian crisis. Material and Resources is not limited to the simple availability of physical goods, but encompasses the entire life cycle of resources: from inventory planning to procurement, from storage to final distribution, up to the management of their use in the field. In an emergency scenario, in fact, the ability to guarantee adequate materials, in sufficient quantity and within the required timeframe, can make the difference between an effective intervention and an operational failure.

Proper resource management first of all implies a structured preparedness phase, with the preparation of pre-positioned stocks at strategic points, the activation of digital stock monitoring systems and the definition of clear protocols for the movement of goods. It's not just about stockpiling materials, it's about knowing exactly where they are, what condition they're stored in, and how they can be quickly made available when needed. In addition, materials must be adapted to the operational context: supplies that are not suitable for local climatic or sanitary conditions can prove useless, or even harmful, aggravating rather than alleviating the crisis. An emblematic case that highlights the crucial role of materials management is represented by the floods in Pakistan in 2022. In the face of a disaster that has submerged more than 85,000 km<sup>2</sup> of territory, with millions displaced and infrastructure severely damaged, the timely availability of materials has proved to be a determining factor in the survival of millions of people. The exceptional intensity of the monsoon rains, combined with the accelerated melting of glaciers, generated a humanitarian catastrophe of historic proportions, which quickly saturated local logistical capacities. In this scenario, the presence of the **Humanitarian Response Facilities (HRF)** network, jointly created by WFP and the Government of Pakistan before the emergency, has made it possible to accelerate the logistical response. These structures, distributed in areas not directly affected by the floods, have made it possible to keep relief materials strategically placed and ready for rapid distribution.

However, despite the HRF network proving to be a key asset, there was no shortage of challenges: the damage to more than 13,000 km of roads and the destruction of 436 bridges compromised the logistics flow, slowing down the delivery of life-saving goods. The procurement of resources was further complicated by the extensive and widespread nature of the emergency: waterproof tents, durable hygiene kits, water purification systems, stable food supplies, medicines and fuel were needed to support the mobility of the

operational teams. Climatic conditions have rapidly degraded unsuitable materials, making it clear that the quality of stored goods was as decisive as their quantity. For example, the lack of adequate tents to withstand extreme weather conditions has resulted in increased exposure of the population to infectious diseases. Another critical aspect was the maintenance of the cold chain for medicines, which was possible thanks to partnerships such as the one with Maersk, which ensured the availability of refrigerated containers. This has made it possible to safeguard the quality of life-saving drugs and vaccines even in extremely difficult operating conditions, avoiding significant losses of highly critical materials. Similar logistical challenges were encountered in the Democratic Republic of the Congo, where UNICEF airlifted 90 tons of health, water, and sanitation supplies to help contain the spread of Ebola in the eastern part of the country. In such high-risk health emergencies, the rapid mobilization and targeted delivery of critical supplies played a key role in supporting the containment effort and protecting vulnerable communities. Likewise, in Nepal, humanitarian relief operations following natural disasters involved the swift distribution of emergency shelter materials, hygiene kits, and safe drinking water to affected populations. These efforts not only mitigated immediate suffering but also helped reduce the risk of secondary crises such as disease outbreaks, demonstrating once again the importance of having a responsive and well-coordinated supply chain.

The management of materials and resources in Pakistan as well as in DRC and Nepal has clearly shown that, in emergency contexts, agility in the reallocation of stocks, the possibility of finding alternative supplies and rapid decision-making are key elements. Experience has shown how it is necessary to integrate material management with information systems updated in real time, capable of tracking stocks, monitoring consumption and predicting emerging needs, in order to prevent both bottlenecks and waste.

## Warehouse

In the management of a humanitarian crisis, the ability to have adequate warehouses is a critical factor that profoundly affects the speed, efficiency and resilience of the operational response. The concept of **Warehouse**, in the context of the humanitarian supply chain, cannot be limited to the physical availability of storage facilities alone: it embraces the entire positioning strategy, the management of logistics flows, the choice of inventory policies and the integration of warehouses within a dynamic and adaptive network.

In the case of the emergency in **Ukraine** starting in 2022, the role of warehouses immediately proved to be crucial. With the main communication routes damaged or blocked and with the closure of airspace, it was necessary to create a new logistical infrastructure capable of supporting the flow of aid from abroad and distributing it over a highly unsta-

ble territory. In this scenario, the **Logistics Cluster**, led by WFP, adopted a **forward positioning** strategy: advanced logistics hubs were quickly activated in Rzeszow, Lublin, Warsaw and Lviv, facilities located in relatively safe areas but close to Ukraine's borders, in order to combine efficiency and protection. The logic behind this choice is profoundly different from that of commercial supply chains. While in the industrial world warehouses tend to be centralized and optimized according to costs, in the humanitarian response the priority objective is to ensure **rapid access** to stocks and **operational flexibility**, even at the expense of economic efficiency. For this reason, the positioning of humanitarian warehouses must follow criteria of **redundancy** (preventing the loss of a single hub from compromising the entire operation), **modularity** (the possibility of rapidly expanding or reducing capacity) and **adaptability** to changing situations on the ground.



Figure 4.17: Snow in Pakistan 2022 [19]

From a management point of view, the organization of warehouses in Ukraine was based on extremely strict inventory policies. In particular, for perishable goods, such as food and pharmaceuticals, the **FEFO** (First Expired, First Out) rule has been applied, which imposes the priority distribution of materials with the shortest expiry date, in order to reduce waste and ensure the quality of the goods destined for beneficiaries. For low-perishable materials, such as tents, blankets, hygiene kits and logistics tools, FIFO (First In, First Out) logic was used, maintaining a regular stock rotation and facilitating batch tracking. This approach is perfectly in line with the best practices adopted by the main humanitarian organizations: WFP, ICRC and DR, for example, employ **real-time tracking** systems and mixed FEFO/FIFO policies, also integrating automated management systems based on SAP, GIS or ERP to monitor in real time the status of stocks, expiration levels and movement flows. This digitalization proved to be crucial in the Ukrainian context, where the speed of operational change required continuous updates and extremely responsive inventory management. A particularly important element in warehouse management has been the creation of strategic **buffer stocks**. The presence of additional stocks, in ad-

dition to immediate needs, has proved essential to ensure the continuity of aid even in the event of sudden blockages, destruction of infrastructure or unforeseen changes in the political and military situation. Similarly, **Mobile Storage Units (MSUs)** — modular and easily assembled structures — were deployed to quickly extend storage capacity in border areas or near the most dynamic operating areas.

The management of warehouse flows has also had to deal with the seasonality of the Ukrainian climate. The particularly harsh winter has forced the adoption of air-conditioned warehouses or, alternatively, the use of refrigerated containers to ensure the preservation of the most sensitive materials, such as vaccines, drugs and health tools. In this sense, the previous experience of organizations such as DR, which implement advanced **cold chain logistics** solutions even in crisis contexts, has been an important reference.

The management of the **last mile**, i.e. the final distribution from logistics hubs to beneficiaries, was one of the most complex challenges. In many areas of Ukrainian territory, roads were impassable, cities isolated or subject to shelling, and the operational risk for personnel was very high. As a result, it was necessary to integrate traditional road transport strategies with more flexible solutions, such as the use of small convoys on secondary routes, the use of alternative means and, in some cases, direct support from the local population for distribution in hard-to-reach areas. The ability to manage warehouses as **dynamic nodes**, rather than static structures, proved to be decisive. Hubs needed to be able to be scaled, relocated, or reorganized quickly, following the evolving war front and ever-changing humanitarian needs. In some critical phases of the conflict, for example, it was necessary to temporarily deactivate some logistical bases and strengthen others, depending on the flows of displaced population and the areas most affected. Finally, the management approach to warehouses had to take into account the diversity of operating partners. Since the Logistics Cluster is based on a network of NGOs, UN agencies and private actors, it was necessary to define shared **Standard Operating Procedures (SOPs)** for the use of spaces, the registration of goods, the management of loading priorities and the distribution of materials. This coordination work, although costly, has ensured greater operational consistency and reduced the risk of inefficiencies or overlaps.

## Funding

Funding is one of the main internal factors that influence the operational capacity of an NGO in managing the humanitarian supply chain. Most humanitarian organizations depend on voluntary contributions from governments, philanthropic foundations, private companies, and individual donors. However, the nature of this funding introduces a number of critical issues that directly impact planning, efficiency, resilience and the ability

to respond quickly to emergencies. A first major challenge is related to the volatility of the flow of funds. Donations tend to grow rapidly in the wake of major media disasters, but they shrink just as quickly as public attention declines or geopolitical and economic priorities change. This unpredictability makes it extremely difficult to implement medium-to-long-term strategies, preventing the development of structured preparedness plans, the creation of pre-positioned stocks and the construction of permanent logistics hubs. The lack of certainty about future funding also discourages investment in innovative technologies and continuous staff training, which are essential for an effective and adaptable response.

Concrete examples of this trend can be seen in recent crises. In Ukraine, as of April 2025, the UN was forced to reduce its humanitarian aid target from 6 million to 4.8 million people due to a sharp decline in global funding, including an 83% drop in contributions from the United States via USAID. This dramatic reduction in available resources directly affected the scale and speed of humanitarian interventions. Similarly, in the Democratic Republic of Congo, while donors provided approximately \$734 million in financial support for the Ebola response from August 2018 through early December 2019, the disbursement and allocation of these funds were uneven over time. Such fluctuations made it difficult to maintain continuous operations, scale up quickly when needed, and invest in long-term infrastructure and logistics capacity that would have supported a more sustainable response. Another critical aspect is the length of funding cycles. Many grants have a limited duration of a few months or, at most, a year, imposing on NGOs the need for an almost continuous process of finding new funds. This obligation to constantly renew funding hampers the ability to manage protracted humanitarian operations, which are particularly necessary in situations of chronic crisis or protracted conflict. In addition, discontinuity of funds can compromise the retention of qualified personnel and the integrity of difficult-built supply chains. In addition, much of the funding is earmarked, i.e. tied to specific projects or activities, severely limiting flexibility in the use of resources. While donors prefer to allocate funds directly to final beneficiaries – such as for the distribution of food, medicine or temporary shelter – funding for critical but less visible support activities, such as logistics management, operational security or the adoption of technology platforms, is often lacking. This imbalance creates a paradox: although many NGOs have materials to distribute, they find themselves without the necessary resources to transport, track or store them properly.

The main NGOs analysed in the research clearly reflect these dynamics. For example, WFP is funded entirely by voluntary contributions and faces highly variable donation cycles, conditioned by global crises and international political dynamics. MSF and DR,

on the other hand, rely predominantly on private donations, which ensures greater operational autonomy but also implies a continued need to maintain public attention to ensure economic sustainability. Similarly, ActionAid and Oxfam, while having access to institutional funds, face the difficulty of obtaining flexible funding for overheads or for strengthening internal logistical capacities, which are key elements to ensure the effectiveness of interventions. A further element of complexity is represented by the management of accountability towards donors. NGOs are required to demonstrate in a transparent and detailed way how the funds received are used, often through rigorous reporting, external audits and complex monitoring systems. While this need improves transparency and strengthens donor confidence, it can also slow down decision-making processes on the ground, imposing administrative constraints that reduce operational agility at precisely the times when a flexible and timely response would be most needed. In dynamic and high-pressure environments, excessive bureaucracy risks compromising the effectiveness of operations.

## Security

Security is an internal factor of primary importance for the operational capacity of an NGO during a humanitarian crisis. In scenarios of political instability, armed conflict or large-scale natural disasters, ensuring the safety of personnel, equipment and logistical facilities is essential to ensure the continuity of rescue operations. However, unlike in other sectors, NGOs do not use active security measures such as the use of armed escorts or private protection forces, as such practices would be incompatible with the principles of neutrality, impartiality and independence governing humanitarian action.

Security management, on the other hand, is based on the rigorous adoption of **preformulated procedures**, designed to minimize risks through the prevention and passive management of threats. These procedures include: the systematic analysis of the risk context (security assessment), the definition of precise limits on movement, the restriction of operational areas to areas considered safe, the obligation to travel at set times, the adoption of evacuation plans, and the implementation of secure and redundant communication systems.

Structured NGOs, such as WFP, ICRC, MSF and IFRC, integrate security as an integral part of operational planning, including dedicated risk management teams, the development of mission-specific security plans and the continuous training of staff. Each operator is trained to recognize warning signs, adhere to strict behavioral protocols in tense situations, and operate with a low profile to reduce their visibility and the risk of attacks. From a logistical point of view, security has a profound impact on the planning of activities.

Convoy routes must be carefully selected and approved, warehouses must be located in areas deemed safe or protected by the local community, and the frequency of missions may be reduced according to the development of the situation on the ground. In some cases, logistics operations are temporarily suspended or modified (e.g. by shifting the focus to remote distribution modes or prepositioning stocks) pending the improvement of the security situation. The NGO approach to security is therefore closely linked to the concept of **acceptance**: instead of imposing their presence by force, the organizations seek to obtain the consent of local communities and actors, building relationships of trust and demonstrating their neutrality.

## Information

Information management is a key element in the operational capacity of an NGO in an emergency context. In highly complex and constantly evolving scenarios, the effectiveness of the humanitarian response depends to a large extent on the speed, reliability and quality of the flow of information between the different actors involved. Unlike the ordinary logistics management of fixed warehouses, where in some cases ERP systems and automated platforms for inventory management can be used, in the emergency response phase, information management is mostly based on leaner and more operational systems, designed to be flexible and adaptable. In these situations, the main goal is not so much to automate the supply chain as to **quickly and accurately share critical data**.

The most relevant information concerns the availability and location of stocks, the situation of transport infrastructure, the safety of routes, the updated needs of the affected populations, and the operational status of the teams in the field. This data is collected on the ground through assessment missions, communications between logistics clusters, updates from temporary warehouses and regular briefings with local partners. The ability to **share information** in a timely manner is essential to avoid duplication of aid, logistical overloads, delays in distribution or gaps in assistance. For this reason, NGOs participate in coordination systems such as Logistic Clusters, which serve as platforms for collecting, consolidating and distributing logistics data. Through collaborative tools such as Situation Reports (SitRep), shared logistics maps, and centralized databases of available inventory, humanitarian workers can quickly align their operations, optimize transportation, avoid warehouse congestion, and direct aid to areas of greatest need.

Concrete examples of recent emergencies highlight the crucial role of flexible and context-adapted information management systems. During the Pakistan Floods of 2022, the lack of reliable communication infrastructure in rural areas prompted the use of alternative channels such as local radio stations and SMS-based systems to disseminate evacuation

alerts and coordinate relief efforts. Simultaneously, the Pakistani government and UN OCHA relied on satellite imagery and disaster dashboards to make informed decisions about the deployment of resources in real time. In the context of the *ongoing conflict in Ukraine*, humanitarian organizations have employed social media monitoring and automated sentiment analysis tools to gain rapid insights into civilian needs and detect disinformation threats. The regular publication of the Ukraine Humanitarian Needs Overview (HNO) and biweekly SitReps has supported synchronized operational planning among NGOs. Moreover, satellite and drone imagery have played a pivotal role in tracking population movements, monitoring border crossings, and assessing damage to critical infrastructure.

The importance of shared data is also reflected in priority planning: precise information on the condition of roads, the accessibility of villages or the evolution of food and health needs makes it possible to redefine distribution routes in real time, to update prepositioning strategies and to respond with greater flexibility to unforeseen events. Another key aspect is the standardization of shared information. The use of predefined templates for logistics reports, unified classification systems for relief materials, and common procedures for updating data improves interoperability between NGOs, UN agencies, and private partners, reducing margins for error and speeding up decision-making.

## Technology

The role of technology in disaster response has expanded rapidly in recent decades, transforming the way humanitarian organizations plan, manage, and execute relief operations. Leveraging digital tools and technological innovations enables responders to act with greater efficiency, speed, and accuracy, ultimately saving more lives and optimizing the allocation of limited resources.

A prominent example of effective technology deployment occurred during the **2015 Nepal Earthquake**, when NASA provided high-resolution satellite imagery and geospatial data to assist humanitarian organizations. This data allowed responders to map damaged and inaccessible regions, assess the extent of devastation, and prioritize the most urgent needs. The use of satellite data significantly reduced the time required for initial damage assessments and helped optimize the allocation of emergency resources. It also improved coordination between governmental bodies, NGOs, and international organizations, enabling faster and more structured delivery of aid to remote and heavily impacted areas.

Likewise, the response to **Hurricane Katrina** in the United States highlighted the growing reliance on cutting-edge technologies for disaster management. After facing

widespread criticism for the delayed and disorganized response, FEMA adopted a variety of digital tools to enhance future emergency preparedness and response capabilities. These included integrating social media platforms like Twitter and Facebook for real-time communication and public updates, deploying smartphone applications to gather and disseminate situational information, and utilizing drones for aerial surveillance and search-and-rescue operations. The incorporation of these tools not only improved situational awareness and information dissemination but also facilitated more accurate targeting of aid and faster rescue efforts.

Moreover, these cases illustrate a broader trend in disaster response: the shift from reactive strategies to proactive, data-driven decision-making. With the help of predictive analytics and real-time data streams, humanitarian supply chains can now anticipate disruptions, model different response scenarios, and adapt logistics plans dynamically based on evolving ground conditions. For instance, geospatial intelligence and AI-based forecasting can identify high-risk zones before disasters strike, enabling the pre-positioning of relief supplies and the development of evacuation strategies.

While technology has tremendous potential for optimizing the humanitarian supply chain, it is still underutilized in the industry today. Most NGOs rely mainly on the experience of senior operators to make operational decisions, basing logistics planning on established models that are often unable to take into account the increasing complexity of contemporary humanitarian scenarios. Innovative tools such as simulation models, what-if analysis platforms, or optimization algorithms for facility locations are available, but still rarely adopted on a large scale. In many cases, the approach is reactive: events are responded to based on the experience gained in previous crises, adapting consolidated strategies without the support of systematic predictive analytics. This lack of innovation limits the ability to anticipate problems, evaluate alternative scenarios, and dynamically optimize resource allocation.

This new technology allows NGOs to integrate quantitative tools into their decision-making procedures, supporting the transformation from an experience-based to a data-driven management model. The ability to test alternative strategies, simulate logistical disruptions, assess the impact of changes in demand or infrastructure changes represents a real opportunity to improve operational readiness and the quality of the assistance provided. These examples underscore the critical role technology plays in modern disaster response and humanitarian logistics. From improving communication and coordination to accelerating damage assessments and optimizing supply delivery, technology enhances nearly every phase of disaster management. As digital capabilities continue to evolve, we can expect even more sophisticated tools to emerge—tools that will further empower

relief agencies to act faster, more accurately, and with a greater understanding of the needs on the ground. Embracing such innovation is not just beneficial—it is increasingly essential for building resilient and responsive humanitarian systems in a world facing growing environmental and geopolitical challenges.

In the next section, the functioning of the developed model will be deepened, highlighting the data used, the hypotheses adopted and the results obtained through two different optimization approaches: one based on genetic algorithms and the other on reinforcement learning.

#### 4.4.6. Model

The main objective of this project is to create **Proof of concept** for the placement of warehouses in the humanitarian field, which implies that the model has simplifying assumptions and that it will need more development. This choice was made because each NGO has very particular requests and parameters regarding the positioning of warehouses; therefore, it would be impossible to cover all eventualities for all the NGOs present or even for the most important ones, also because some may contradict others. In addition, depending on how much an NGO wants to integrate this methodology within the standard procedures for operations.

The purpose of this proof of concept is to show organizations how such a tool can help them make more informed decisions about warehouse layout and can offer insights that haven't been considered. In addition, this tool opens up different possibilities for data analysis and optimization such as "What if analysis" and other testing of different scenarios, all practices that can help organizations increase agility, resilience and efficiency resulting in an increase in the level of rescue that can be provided.

#### Data

In this part we will discuss how the model was built, what data was taken into account, what simplifying assumptions were used and what optimization algorithms were implemented for the creation of this tool. The data that allowed the creation of this simulation come from the **LC, Humanitarian Data Exchange (HDX), WorldPop (WP), Open Street Map (OSM), the Nepalese government and the WFP.**

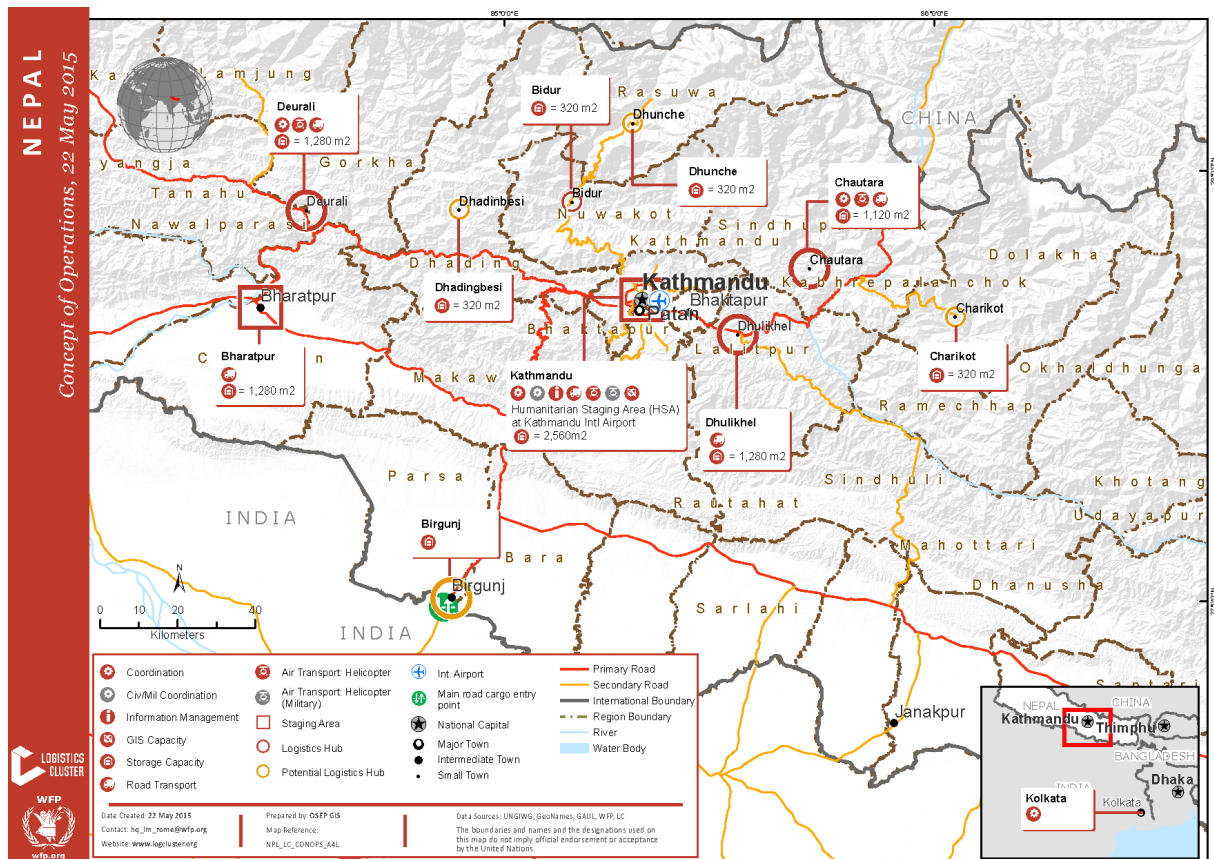


Figure 4.18: Concept of Operations [20]

**Warehouses, Vehicles and Roads** Through the LC website it was possible to retrieve what the layout of the regional warehouses was during the first days of the emergency. Regional warehouses are fixed structures that are rented and very often the choice of these locations is limited and unpredictable as there are many requirements in order for a warehouse to be in compliance with the policies of the NGO. Having concluded the premise, the warehouses taken into consideration are:

1. Bharatpur – capacity: 1280 m<sup>2</sup>
2. Dhulikhel – capacity: 1280 m<sup>2</sup>
3. Charikot – capacity: 320 m<sup>2</sup>
4. Dhunche – capacity: 320 m<sup>2</sup>
5. Bidur – capacity: 320 m<sup>2</sup>
6. Dhadingbesi – capacity: 320 m<sup>2</sup>
7. Deurali – capacity: 1280 m<sup>2</sup>

8. Chautara – capacity: 1120 m2

As for the roads, on the other hand, they were recovered from OSM of 2015, which gives the map as a graph where each line is a road and there are nodes that represent the end of the roads or POIs, for the possible locations of the warehouses, to be allocated, all the nodes (62817 possible positions) will be considered. On the other hand, travel times and distances will be used those present on OSM, in case no data on the average travel speed are available, a fallback of 30 km/h will be used.

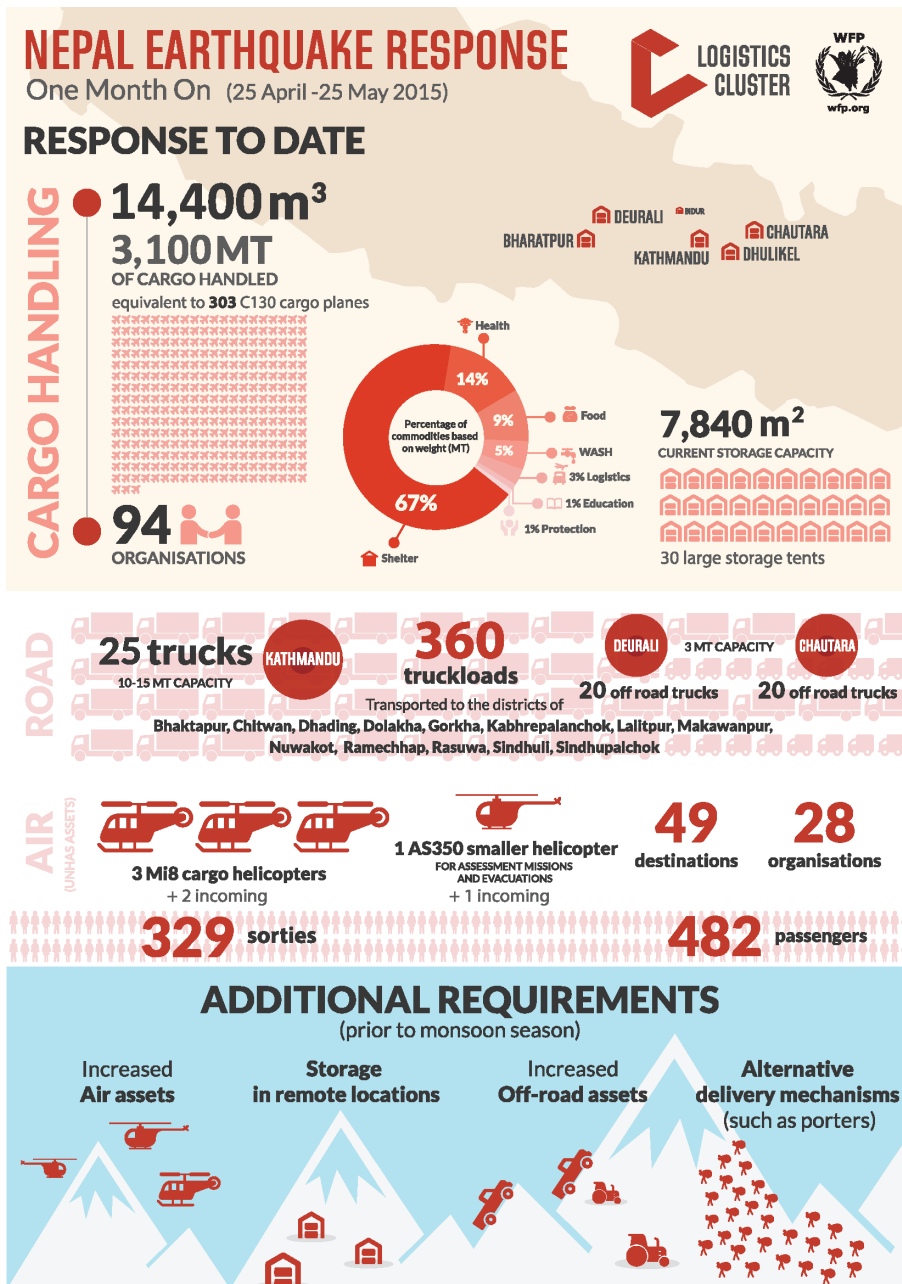


Figure 4.19: June 2015 Monthly Report [20]

For the vehicles, those indicated in the meeting minutes and in the monthly reports were taken, so each regional warehouse has **20 off-road vehicles** that can carry **3 metric tons**. As for transport by Sherpa or helicopter for this simulation, they were not taken into consideration.

**Territory, Population and Demand** As for the boundaries of the territory, the data were obtained from the Nepalese government website, with the administrative boundaries and districts. Instead, for the population, a map made available to WP was taken with the number of inhabitants of Nepal for each square kilometer.

Instead, the data reported by IRC's "Nepal: Earthquake: One-year progress report" *was taken as the data for the people affected and the area of intervention*, the simulation considers only the people and positions available within these districts.

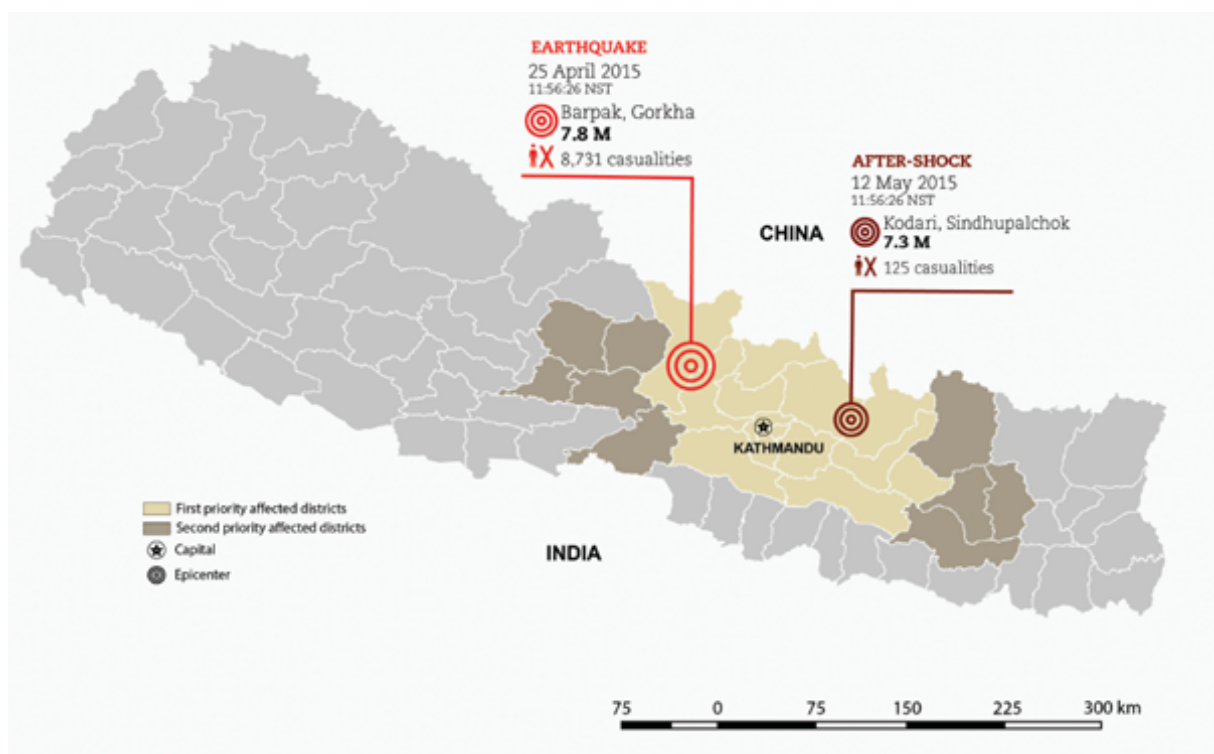


Figure 4.20: Affected Zones [15]

Finally, the demand was taken from the monthly report and is **3100 metric tons** which was redistributed in parts over the report period, i.e. **over 30 days**. In addition, the conversion factor between square meters and tons has been calculated, again through the report, at **0.21527 mt/m<sup>2</sup>**, this data will be used to convert the size of the warehouses to be allocated, which is in square meters, in metric tons. This factor was derived from the report by dividing the weight of aid brought by the aid area.

The warehouses to be placed are **30 Mobile Storage Units (MSUs)**, they are tents that can store a certain amount of material and have a size that can reach up to 10m x 32 m. Given the possibility of different sizes of the MSU, the average value for all the MSUs of 261.33 square meters will be used in the model, which converted to **56.26 metric tons** per MSU, this result comes from the numbers in the monthly report.



Figure 4.21: MSU of the WFP [38]

## Hypothesis

1. These are all the simplifying assumptions that have been used within the model:
2. *People are in distress are distributed in the same way as the distribution of the population in the affected areas.*
3. *Vehicles can only pass on the roads marked on OSM (This hypothesis can be eliminated if the organization collaborates with a private mapping company).*
4. *The blocked roads are only those marked on OSM.*
5. *No distinction will be made between relief goods, but only tons of goods moved will be considered (You would need to have a detailed list of all shipments to remove this assumption).*
6. *All people need the same amount of goods constantly. (This is not too stringent as the tool should be used in the first few weeks after the outbreak of the emergency.)*

7. *In the regional warehouses there are already all the necessary materials or in any case shipments are always on time.*
8. *The locations of regional warehouses cannot be changed.*

**Structure and Constraints** Two different algorithms were used with the creation of two optimization models, to compare their performance and give an offer and a greater vision on a possible implementation of this working methodology, for each model the same constraints for optimization were applied:

- MSUs must be associated with a number of question cells such that the total demand does not exceed their capacity divided by 10.
- Regional warehouses must be associated with the number of MSUs so that in 10 days they can make the journey to all MSUs at least once.

The algorithms used are a genetic algorithm and a machine learning model, in particular reinforcement learning with a PPO algorithm, both of which will be explained in more detail in the following paragraphs.

**Genetic Algorithm** Genetic Algorithms (GA) constitute a class of stochastic meta-heuristics belonging to the paradigm of evolutionary computing. They draw inspiration from the mechanisms of Darwinian biological evolution and the principles of Mendelian genetics to solve optimization and search problems in complex and large-dimensional solution spaces. GAs are particularly effective in contexts where analytical or deterministic methodologies are computationally intractable or fail to converge towards globally optimal solutions. The algorithmic process of a GA operates on a population of candidate solutions, defined as individuals or chromosomes. Each individual represents a potential solution to the problem under consideration, typically encoded by means of a data structure. The iterative procedure is divided into the following fundamental phases shown in the graph fig. 4.22 The intrinsic goal of Genetic Algorithms is, therefore, to guide the evolution of the population towards regions of the space of solutions containing individuals characterized by high fitness values, which correspond to high-quality, potentially optimal or sub-optimal solutions for the optimization problem considered. In practice, each candidate represents a possible configuration of the thirty MSUs: an individual is therefore a vector of identification of the road junctions where the tent-warehouses can be installed. The GA was chosen because it effectively addresses positioning problems with multiple constraints (capacity of regional centres, number of vehicle trips, compliance with maximum service times) and with an extremely large and non-linear solution

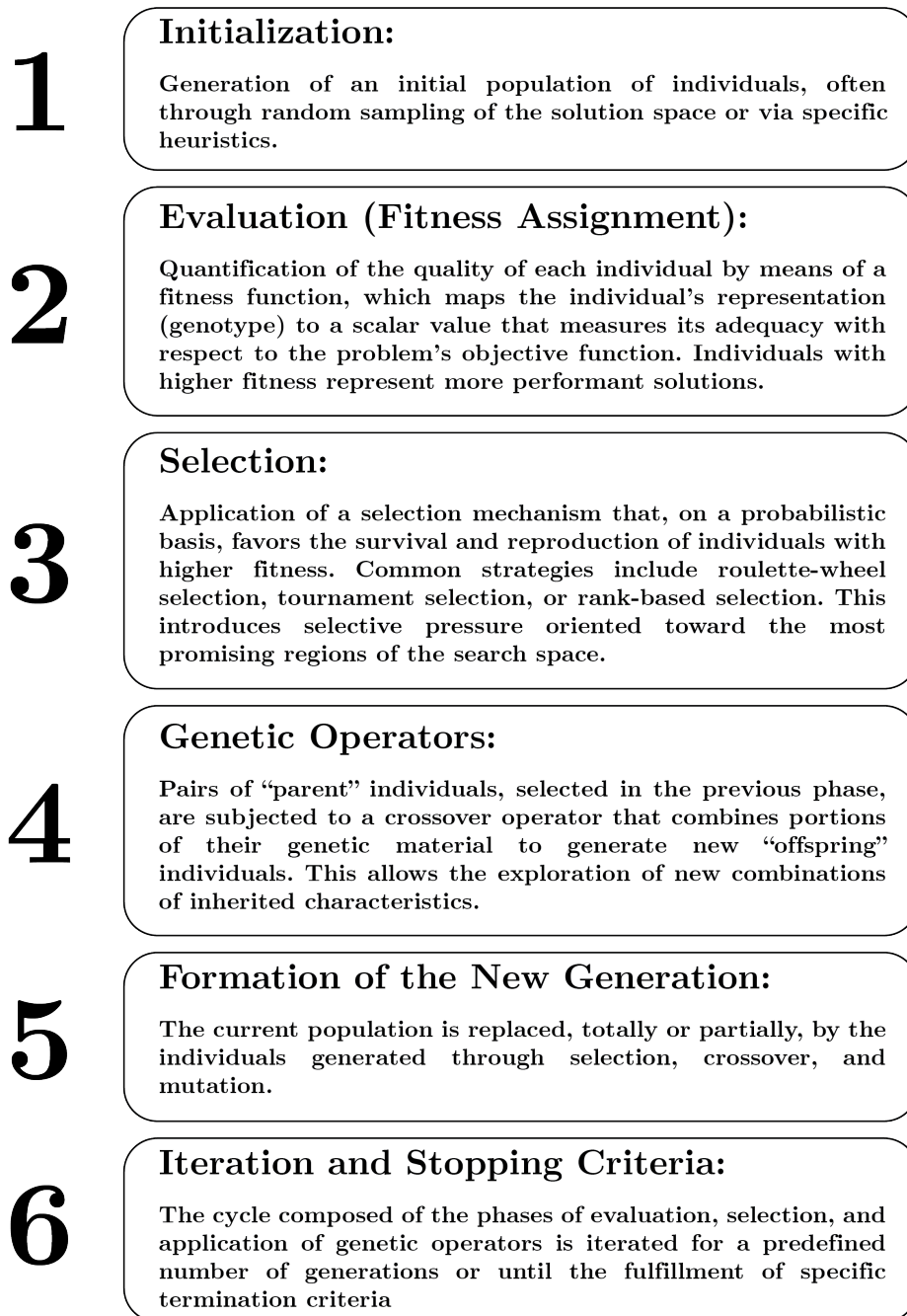


Figure 4.22: GA steps

space: in these conditions, deterministic approaches risk stopping in excellent premises or requiring prohibitive calculations. Stochastic evolution, on the contrary, allows us to explore more areas of the domain and to quickly produce "good enough" solutions, even without deriving gradients or convexity guarantees.

**Machine Learning** The **Proximal Policy Optimization (PPO)** algorithm represents an advanced methodology in the field of **Reinforcement Learning**, specifically classified among the **policy gradient algorithms** operating in **on-policy** mode. The PPO aims to optimize the agent's stochastic policy in order to maximize the **expected value of the discounted cumulative return**. Its distinctive feature lies in introducing mechanisms aimed at ensuring a more stable and efficient learning process than traditional policy gradient methods, mitigating the risk of performative collapse due to excessively large policy updates. PPO addresses the issue of update instability by optimizing a **surrogate target function**, but with a crucial change from previous methods. The two main variants of PPO are:

- **PPO-Clip:** This is the most popular version. It introduces a **limitation on the ratio between the probability of an action under the new policy and the probability under the old policy** used to generate the data. The surrogate goal is calculated by taking the minimum of two terms: the first is the product of the aforementioned probability ratio and the estimate of the **advantage function**; the second term is similar, but the probability ratio is first "bounded" within a narrow range around the value one, defined by a specific hyperparameter. This limitation prevents policy updates that deviate too much from the previous one, keeping the update in a sort of implicit "region of trust" and promoting stability. The maximized end goal is often a combination of this limited surrogate term, an error term for value function estimation, and an entropic bonus to encourage exploration.
- **PPO-Penalty:** This variant uses a **penalty based on the Kullback-Leibler divergence** between the new and old policies. This penalty, which measures the "distance" between the two probability distributions of policies, is added as a regularization term to the unbounded surrogate goal. A coefficient that multiplies the penalty is dynamically adjusted during training to keep the divergence within a desired target range, achieving a regularization effect similar to that of clipping.

PPO is typically implemented using an **Actor-Critical** architecture. An "Actor" neural network approximates the agent's policy, while a "Critical" network approximates a **state value function**, which is used to calculate estimates of the advantage function. The algorithm operates iteratively: it collects a set of trajectories (experiences) using current policy, calculates estimates of benefits for these experiences, and then performs multiple optimization steps on the surrogate goal function using the collected data. In practice, the agent learns a policy that decides how to place the 30 MSUs while maximizing the reward, defined as negative of the maximum service time penalized.

## Results

The quantitative results indicate a marginally superior performance for the Genetic Algorithm. This methodology has identified a logistical configuration that allows a maximum service time of 6.56 hours to be achieved. The PPO-based implementation, on the other hand, produced a solution with a maximum service time of 6.84 hours. Although this is a small difference (approximately 0.28 hours), it suggests that, under the defined experimental conditions, the GA reached a solution closer to optimal than the objective metric.

It is crucial to note that both techniques generated admissible solutions with respect to the operational constraints imposed. The PPO model, in particular, returned a zero penalty value, certifying full compliance with the constraints implemented in the learning process. Similarly, the GA's fitness function is structured to penalise or exclude solutions that violate the operating conditions, ensuring the admissibility of the final solution.

The observed divergences can be traced back to the different optimization strategies intrinsic to the two algorithms. GA operates through simulated evolutionary processes (selection, recombination, mutation) on a population of candidate solutions, exploring the solution space in a stochastic and parallel manner. Analysis of the GA execution logs shows effective convergence to values close to the final solution identified. Reinforcement Learning with PPO, in contrast, relies on an agent learning a decision-making policy, guided by a reward cue from interacting with a simulated environment. The inherent stability of PPO mitigates the risks of overly large policy updates, but the final performance can be affected by the definition of the reward function, the configuration of hyperparameters, and the duration of the training phase.

In summary, the study conducted as part of this "Proof of Concept" demonstrates the feasibility and usefulness of both evolutionary metaheuristics and machine learning techniques to address complex problems of facility location in the humanitarian field. Although the Genetic Algorithm produced the best quantitative result in the specific scenario, both approaches provide robust and practically usable solutions. The selection of a methodology for future operational implementations should consider factors such as the computational efficiency required, the need for dynamic adaptability, and the available technical resources. Both models, however, fulfill the design purpose of providing quantitative tools to support more informed decision-making processes and to conduct scenario analysis.

Indicator	Genetic Algorithm	Reinforcement Learning (PPO)	Comment
Maximum service time (hub → MSU → demand)	<b>6.56 h</b>	6.84 h	GA reduces the most critical delivery time by $\approx 17$ minutes (-4%), which is particularly valuable in the first 72 hours of an emergency.
Reward/fitness	Fitness = 6.56 h (minimized)	Reward = -684.26 ( $\approx -100 \times$ time)	The values are not directly comparable, but both reflect the same goal of minimizing service time.
Penalties (Constraint Violations)	0	0	Both models fully comply with the constraints of capacity, travel, and time.
Calculation time	2 333 s ( $\approx 39$ min)	11 919 s ( $\approx 3$ h 19 min)	The GA converges $\approx 5$ times faster in the case study.
Key Parameters	Population 100, 100 sequential generations	2 500 timesteps, 128-128 neural network, PPO-Clip method	GA is simple to calibrate; PPO requires careful tuning (learning rate, clip, n-steps).
<i>(Continued on next page)</i>			

Indicator	Genetic Algorithm	Reinforcement Learning (PPO)	Comment
Robustness / generalization	High quality on a fixed scenario; each new context requires reworking the entire evolution.	Once trained, the agent can re-optimize online or move to other theaters with limited fine-tuning.	
Scalability	Computational costs grow rapidly with multiple MSUs or candidate nodes.	The main cost is training; inference remains very fast (milliseconds).	

Table 4.15: Comparison between Genetic Algorithm and Reinforcement Learning (PPO)

The adoption of an advanced optimization model, such as the one developed in this "Proof of Concept", offers numerous concrete advantages for humanitarian organizations. Firstly, it allows unprecedented speed in the analysis of multiple scenarios: thanks to automation and the ability to quickly explore a wide range of solutions, it is possible to evaluate different logistics configurations in a much shorter time than traditional methods. This accelerates response capacity, which is especially crucial in the first hours and days of an emergency.

The model also allows for extremely detailed analyses. Decisions can be supported by objective and precise metrics, such as service times, warehouse load, distribution routes and vehicle utilization. It becomes possible to carry out "what-if" simulations and quickly test the impact of variables such as infrastructure blockage or changing demand. This level of insight enriches strategic and operational planning, increasing the agility and resilience of the humanitarian response.

From the point of view of scalability, models based on genetic algorithms or reinforcement learning prove to be extremely effective: even in the presence of a large number of mobile warehouses, vehicles or candidate geographical points, they are able to maintain competitive calculation times without sacrificing the quality of the solution found. In addition, the fact that each proposed configuration is derived from concrete data and well-defined constraints makes the decision-making process more transparent, improving documentation and facilitating discussion with stakeholders. All these aspects ultimately translate into a real improvement in humanitarian operations: thanks to a more efficient management of resources and a reduction in delivery times, it is possible to increase the quality and

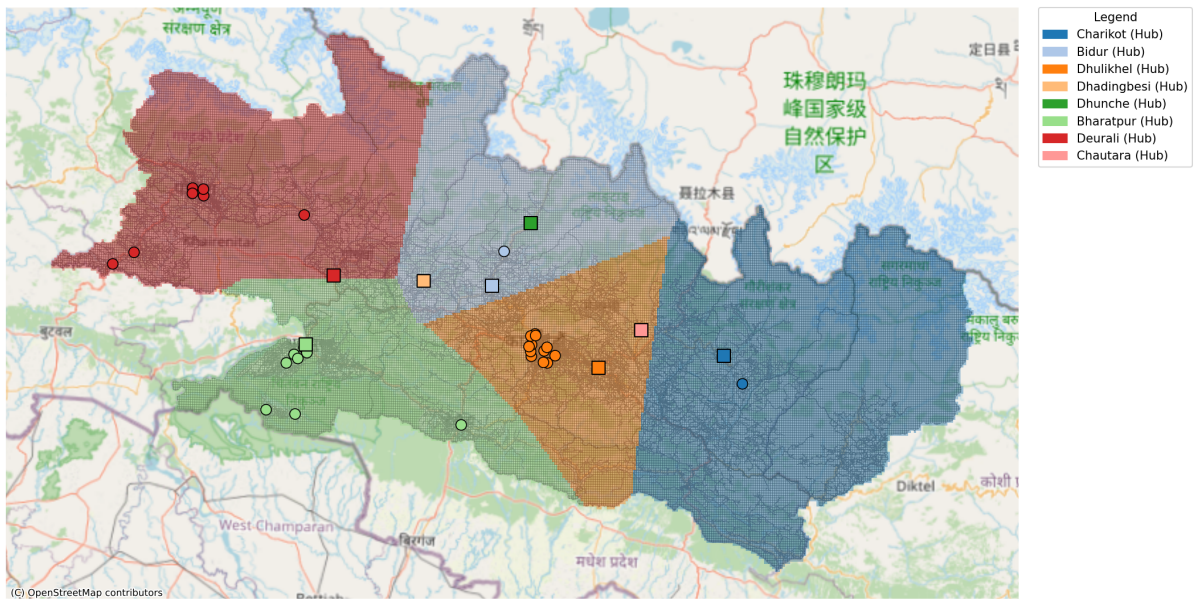


Figure 4.23: Map of the best MSU Location

extent of the relief provided to the affected populations, maximizing the positive impact of the intervention.



# 5 | Results

At the conclusion of the research, an empirical study was conducted using the Delphi method. This methodology, renowned for its effectiveness in generating expert consensus, enabled the collection of insights from professionals operating in critical and geographically dispersed contexts. The use of Delphi ensured a structured and iterative process of collective reflection, capable of producing a clear hierarchy of the factors considered most influential in determining the success or failure of a humanitarian response. The aim was to bridge a more academic approach, capable of producing a list of potential improvements to the HSC with a practical perspective, in order to suggest interventions in the most critical areas for field practitioners.

After data collection, means, medians, and interquartile ranges were calculated and returned to the participants, who were invited to reflect on instances where their opinions diverged from the group's. In the second round, respondents could confirm or revise their initial responses: dispersion significantly decreased (the average absolute delta dropped from 1.02 to 0.37 points). In other words, the Delphi process yielded not merely a list of priorities, but a reasoned consensus reflecting the experience of humanitarian managers.

## 5.1. Factor Ranking

fig. 5.1 graphically summarizes the distribution of scores using a box plot. Data analysis highlighted the centrality of five macro-factors: availability and **management of material resources**, flow and transparency of **information**, **warehouse** efficiency, development level of the operating context, and staff training. These elements were unanimously recognized as fundamental pillars for building a solid and effective humanitarian response.

Among these, the **management of material resources** emerged as the top priority. Interviewed NGOs emphasized the importance of accurate procurement planning, collaboration with reliable local and international suppliers, and the creation of buffer stocks in strategic areas. In recent operations, from the Ukraine crisis to the Turkey earthquake, the lack of essential goods compromised the timeliness of aid and increased the vulnerability

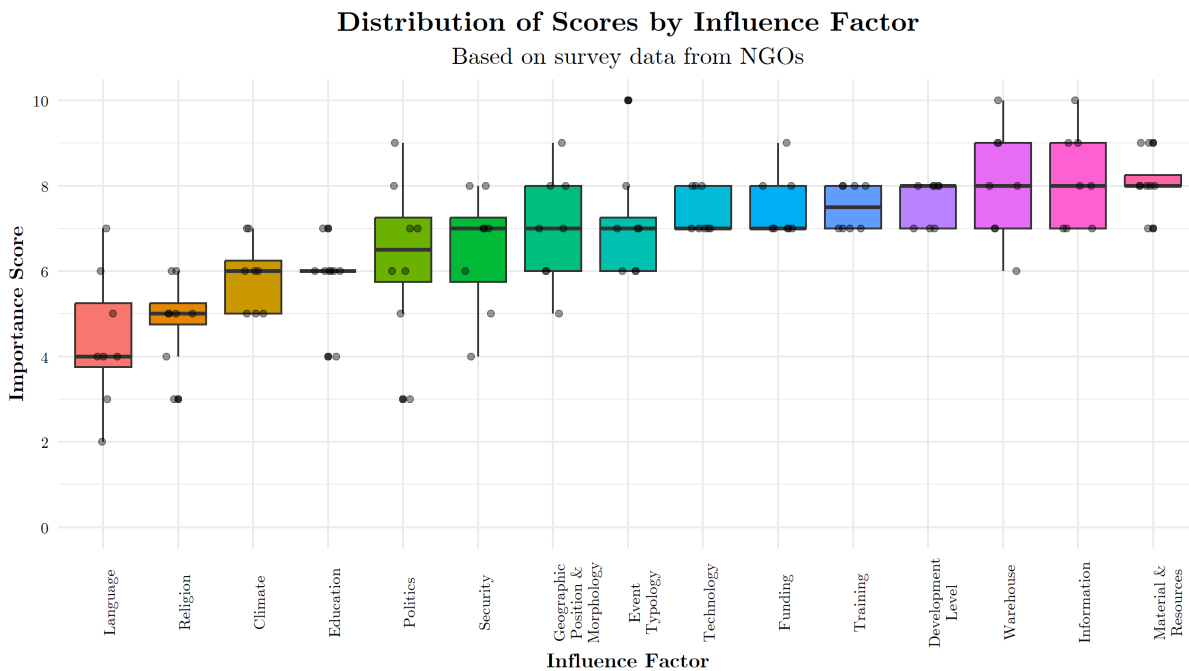


Figure 5.1: Delphi Results

of affected populations. Well-stocked warehouses, equipped with automated management systems and connected to inter-organizational platforms, can make the difference between effective and ineffective response.

The second factor **information** received surprisingly high ratings. This encompasses not only quantitative data, but also their quality, accessibility, and ability to generate trust among operational partners. Professionals involved highlighted how, too often, the absence of a common platform or the reluctance to share data undermines coordination. Cited examples include information blackouts between UN agencies and NGOs, or the inability to update beneficiaries' needs in real time. Investment in interoperable technologies, data collection automation, and digital staff training emerged as an imperative.

The third critical element, **warehouse**, is closely linked to logistics. The use of tracking tools, such as RFID systems, remains limited but is deemed essential by those working in crisis zones. Many participants advocated for greater standardization of warehouse layouts, adoption of shared KPIs, and the creation of specialized emergency logistics teams. Additionally, pre-mission logistics audits were proposed to assess storage center readiness in advance and find the best location for the need of the mission.

The factors **Development Level**, **Training**, **Funding**, and **Technology** had average scores between 7 and 8. They act as amplifiers: fragile infrastructure, poor training, or unstable funding can nullify the benefits of adequate stock levels; conversely, in the

presence of robust systems, they help mitigate the impact of external constraints.

**Language, religion, climate, and education** showed lower but non-negligible medians. The participants' assessments suggest that while such variables can have negative impacts (e.g., suspensions of distributions during Ramadan or road blockages due to monsoons), they are increasingly manageable thanks to standard protocols and mature technologies.

## 5.2. Average Scores by NGO

In addition to factor ranking, the average score assigned by each NGO participating in the Delphi panel was calculated. This metric helps identify structural differences in operational priorities among the organizations involved.

Fattore	WFP	IRC	OX	MSF	LC	DR	AA	EE
Event Typology	7	7	8	6	10	7	6	6
Geographic Position & Morphology	8	7	7	8	9	6	6	5
Development Level	8	8	7	8	8	7	8	7
Climate	5	7	7	6	6	6	5	5
Politics	6	7	6	5	9	7	8	3
Language	5	7	5	4	9	6	8	3
Education	6	6	6	5	7	6	6	5
Religion	5	6	5	5	6	6	6	4
Training	7	7	6	6	8	7	6	5
Material & Resources	9	7	6	6	9	8	8	6
Warehouse	7	6	6	6	9	8	8	6
Funding	8	7	7	5	9	9	8	7
Security	6	8	7	6	7	7	6	6
Information	8	8	7	6	8	8	8	6
Technology	8	8	7	6	8	7	7	6
<b>Average</b>	<b>6.87</b>	<b>7.13</b>	<b>6.60</b>	<b>5.93</b>	<b>8.27</b>	<b>7.07</b>	<b>7.00</b>	<b>5.40</b>

Table 5.1: Survey Results with Averages by Organization

The results show that the Logistics Cluster assigned the highest average score (7.73), followed by WFP, ICRC/IFRC, and Direct Relief with an average of 7.00. MSF is slightly lower (6.87), while Oxfam (6.47), Action Aid (6.40), and Emergency (6.07) gave overall

lower evaluations.

These differences directly reflect the missions and operational structures of the analyzed NGOs. Agencies with a strong logistical focus, such as WFP and the Logistics Cluster, attribute greater importance to technical and infrastructural factors. In case studies related to the Ukraine crisis and the Turkey earthquake, operational warehouse readiness, flow automation, and buffer stock availability in strategic areas were clearly emphasized. Conversely, NGOs with a more medical or social orientation, like Emergency or Oxfam, assign relatively lower scores to these aspects and focus more on local context, security, and accessibility factors.

The average score per NGO therefore provides a clear indication of the value hierarchies guiding the strategic and operational choices of the various organizations. This interpretation aligns with insights gathered during qualitative interviews, which revealed a marked distinction between logistics-infrastructure and community-based approaches. These differences not only explain the variation in attributed scores but also offer an opportunity for future convergence and collaboration, where complementary skills can be synergistically leveraged.

### 5.3. Improvements

Despite unanimous recognition of their transformative potential, simulation models remain sparsely adopted in the humanitarian sector. Only a few NGOs, among them WFP and the Logistics Cluster, have begun to use predictive tools to plan emergency scenarios, but such practices remain the exception. According to Delphi participants, this is due to two main factors: lack of in-house technical expertise and cultural skepticism toward tools perceived as overly academic or complex. Simulation models based on agent-based or digital twin logic can help:

- anticipate congestion in logistics flows,
- optimize stock allocation,
- assess the impact of exogenous variables (weather, accessibility, security),
- compare alternative scenarios (centralized vs. decentralized response),
- train teams using serious games.

A prototype simulation model developed during this thesis demonstrated the potential of such tools in supporting daily operations. The structured integration of simulation into HSC governance could represent a qualitative leap. This would not just be an operational

support, but a new planning culture: proactive, adaptive, and evidence-based.

One of the strongest themes to emerge during the research was the importance of training. Most operators noted that humanitarian logistics is often learned on the field without a structured path. While this empirical approach highlights adaptability, it also exposes teams to avoidable errors and slows innovation. In this context, a strong proposal emerged to create an organic collaboration between NGOs and universities with the aim to:

- engage young professionals in humanitarian hackathons or collaborative simulations.
- enable NGOs to access updated skills.
- provide visibility for universities through socially impactful projects.

Such synergy would generate value on multiple levels: it would improve the quality of interventions, make humanitarian work more attractive to younger generations, and stimulate applied research. Moreover, it would help address a critical issue identified by experts: high staff turnover and difficulty retaining stable know-how.

The proposal aims to create a collaborative platform between universities and NGOs, conceived not merely as a repository of occasional or thematic courses, as in many current initiatives, but as a truly integrated educational ecosystem. This project aspires to fill one of the most critical gaps identified in the research: the absence of structured training paths for humanitarian workers, especially those in highly technical or strategic roles, such as logistics managers. Unlike traditional e-learning platforms, this initiative would function as a streamlined but coherent academic program, co-designed with direct input from NGOs to meet the concrete operational needs expressed by field professionals.

The primary objective is to ensure that key profiles entering NGOs possess immediately applicable, up-to-date, and field-relevant skills. Participating organizations could incorporate this into mandatory onboarding for specialized roles or direct staff to these modules as needed. This would partially standardize technical preparedness across the humanitarian community, reducing reliance on purely empirical or experiential learning.

To ensure economic sustainability and broad geographical reach, the training program would be distributed across multiple universities, each contributing specific modules based on its unique expertise. Institutions offering more courses, or coordinating core content, would assume the role of primary stakeholders within the platform's governance. This structure not only reduces overall project costs but also leverages academic specialization and local excellence.

In parallel, the proposal envisions gradually expanding the training offering over time.

While the initial focus will be on technical roles, such as logisticians, data analysts, and operations coordinators, network expansion would allow the integration of modules dedicated to other essential roles in the humanitarian context, including managerial, administrative, and strategic positions. Managing a Humanitarian Supply Chain today requires complex, cross-disciplinary skills: financial planning, geopolitical analysis, intercultural negotiation, and multi-level governance. All of these areas demand continuous updates, made even more urgent by international instability and the growing interconnection between environmental, health, and social crises.

## 6 | Conclusion

This thesis aimed to analyze Humanitarian Supply Chains (HSCs) to identify the critical factors that determine their effectiveness in the context of natural disasters and large-scale disruption events. The exponential increase of such crises on a global scale, as highlighted in the introduction, makes a profound reflection on the methodologies and strategies adopted by humanitarian actors imperative. Starting from a research question geared towards the optimization of logistics flows, the study evolved to answer a more fundamental question: what are the variables that truly influence the success of a humanitarian response, and how can they be ranked to guide future improvements?

### 6.1. Obtained Results

The analysis conducted has led to significant results on multiple levels. The most relevant contribution is the identification and ranking of critical success factors through a Delphi methodology involving professionals from nine of the world's leading NGOs. The results of this empirical study clearly highlighted a triad of priority factors: the management of **Materials and Resources** (average score 8.2), the quality and transparency of **Information** (average score 8.1), and the efficiency of **Warehouses** (average score 8.0). These elements, unanimously recognized as fundamental pillars, surpass other traditionally considered central variables in perceived importance.

The analysis also allowed for the development of an original causal model that distinguishes between "Humanitarian Aid Demand" and "Humanitarian Aid Supply." Demand is shaped by external factors such as the type of event, the geopolitical context, and the level of infrastructural development, while supply is determined by internal factors within the organizations, such as training, funding, and governance. This framework not only offers a structured interpretation of the complex interaction between variables but also helps to contextualize the Delphi results, showing how the top-rated internal factors (Materials, Information, Warehouses) are the direct levers on which NGOs can act to optimize their "supply" of aid.

Added to this is another result that is methodological in nature, yet of great practical value: the application of the Analytic Hierarchy Process (AHP) to create a ranking of humanitarian crises. Faced with an ever-increasing number of disasters and conflicts, this tool allowed for a structured and objective selection of the most significant case studies for this thesis, based on a weighted set of variables such as the number of displaced persons, casualties, the Logistic Performance Index (LPI), and economic impact. The creation of two distinct rankings for natural disasters and conflicts not only validated the selection of the analyzed cases but also offers the academic and practitioner community a replicable framework for prioritizing attention and resources towards crises of greater logistical relevance, thus guiding future research and analysis.

Finally, the creation of a *Proof of Concept* simulation model for optimizing warehouse placement in the case study of the Nepal earthquake has demonstrated the potential of advanced quantitative tools. Although a prototype, the comparison between a Genetic Algorithm and a Reinforcement Learning model highlighted how such technologies can provide robust solutions and support faster, more informed decisions, moving beyond the predominantly experience-based approach that still dominates the sector.

### 6.1.1. Research Questions

This thesis contributes to the existing body of knowledge on HSCs in several ways, confirming some theories, adding new nuances, and proposing new research directions.

- **Confirmation of current knowledge:** The research confirms the validity of established frameworks such as Kovács and Spens' disaster management phases (preparedness, response, recovery) and the applicability, with due adaptations, of the principles of Lee's Triple-A Supply Chain (Agility, Adaptability, Alignment) to the humanitarian context. The analysis of case studies reiterated the critical importance of inter-agency collaboration and public-private partnerships, a central theme in the sector's literature.
- **Addition of new knowledge:** The most original contribution of this thesis lies in the **empirical ranking** of critical success factors. While qualitative literature identifies a wide range, few studies offer a prioritization based on the consensus of a panel of international experts. The clear prominence given to the triad of Materials-Information-Warehouses represents new and highly practical knowledge. Furthermore, the "Humanitarian Aid Demand/Supply" conceptual model provides an innovative interpretive framework for structuring the complexity of humanitarian operations. Finally, the thesis addresses a gap identified in the literature by

proposing an **integrated training model between universities and NGOs**, designed to bridge the gap between academic skills and the operational needs of the sector, particularly for logistics roles.

- **Refutation or revision of current knowledge:** The thesis does not directly refute existing theories but contextualizes their scope. For example, it demonstrates how the direct import of commercial models (e.g., SCOR) is inadequate unless accompanied by profound adaptations to the volatility and stakeholder complexity of the humanitarian world. Moreover, the low score attributed to factors like religion or language suggests that, while important, these barriers are now considered more manageable compared to the structural challenges of logistics and information, perhaps thanks to mature operational protocols.

### 6.1.2. Limitations of the Study

Despite its methodological rigor, this study has several limitations that define the validity domain of its results and suggest directions for future research.

1. **Sample Size:** Although the nine participating organizations are major global players, the sample is not representative of the entire humanitarian sector, which includes countless local and national NGOs. Their perspectives could differ significantly. Similarly, the Delphi panel, though composed of experts, is numerically limited, and its expansion could further refine the factor ranking.
2. **Generalizability of Case Studies:** The five analyzed cases were selected through a structured process (AHP) but do not cover all types of crises (e.g., pandemics, technological disasters). The results, while robust, may not be fully generalizable to contexts with radically different dynamics.
3. **Simplifications of the Optimization Model:** The *Proof of Concept* developed for warehouse placement is based on numerous simplifying assumptions, such as uniform demand distribution and homogeneity of goods. It is a demonstrative tool, not a solution ready for operational use, and its validation would require real, non-aggregated data and more complex constraints.
4. **Data Availability:** A constant challenge was the difficulty in obtaining disaggregated and standardized quantitative data from NGOs, often due to security protocols or the lack of homogeneous data collection systems. This necessitated a strong reliance on qualitative interviews and aggregated data.

These limitations open the way for **future developments**: it would be desirable to

extend the analysis to a larger sample of NGOs, apply the factor framework to new types of crises, and above all, develop the simulation prototype into an operational platform in direct collaboration with a partner organization, using real-time data.

## 6.2. Final Conclusions

In summary, this thesis has traced a path that, starting from the observation of a growing humanitarian need, has led to the identification and prioritization of the critical factors that determine the success of humanitarian supply chains. The work has shown that, beyond the challenges imposed by external contexts, humanitarian organizations can drastically improve their effectiveness by acting on well-defined internal levers: strategic management of material resources, a transparent and collaborative flow of information, and an agile and well-positioned warehouse network.

The added value of this research lies not only in providing a "snapshot" of the state-of-the-art but also in proposing concrete tools for the future: a **conceptual model** to analyze complexity, a **framework of priority factors** to guide investments, and, above all, a **strategic vision** to fill two fundamental gaps in the sector: the lack of structured training and the underutilization of simulation and optimization technologies.

The proposal to create an integrated educational platform between universities and NGOs and the call to move from experience-based management to a *data-driven* one are not mere recommendations but represent a genuine paradigm shift. In a world where crises are increasingly interconnected and complex, efficiency, resilience, and collaboration are no longer an option, but a moral imperative. Investing in skills, technologies, and synergies is the primary path to ensure that humanitarian aid not only reaches its destination but does so in the fastest, most effective, and most humane way possible, maximizing the number of lives saved.

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# A | Appendix


## A.1. Interview Model

 <b>POLITECNICO MILANO 1863</b>   DIPARTIMENTO DI INGEGNERIA GESTIONALE	
<h3>Humanitarian Supply Chain Survey</h3> <p><b>Humanitarian Supply Chain Survey</b>            This questionnaire was designed to collect data useful for the development of the thesis entitled:            "Humanitarian Supply Chain: An Analysis of Supply Chain Responses to Natural Disasters and Large Disruption Events."            Even a partial completion can provide valuable information.</p> <p>For any clarification, please contact:</p> <ul style="list-style-type: none"> <li>• Mattia Longobardo (<a href="mailto:mattia.longobardo@mail.polimi.it">mattia.longobardo@mail.polimi.it</a>)</li> <li>• Matteo Schiattarella (<a href="mailto:matteo.schiattarella@mail.polimi.it">matteo.schiattarella@mail.polimi.it</a>)</li> </ul>	
<b>Data:</b>	
<b>Place:</b>	
<b>Name and Surname:</b>	
<b>Organization:</b>	
<b>Role:</b>	
<b>Years of service:</b>	
<b>Previous experience in supply chain:</b>	
<b>Previous experience in humanitarian associations:</b>	
<b>Email:</b>	

1

 <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE	<p style="text-align: center;"><b>SECTION 1: INFORMATION ABOUT THE ORGANIZATION</b></p> <p><i>In this section, we delve into the organization's structure and how emergencies are managed from both a logistical and decision-making perspective.</i></p> <p>1. What is the hierarchy of the supply chain in your organization?</p> <p>2. Are you an independent organization? Do you rely on public funds?</p> <p>3. When you face an emergency, what do you do? Are there specific phases you follow? Do you have any kind of protocol?</p> <p>4. Do you have predefined models that you apply based on the type of emergency (earthquake, flood, volcanic eruption, war)? For example, do you have specific kits that you send depending on the type of emergency and the estimated number of people involved?</p> <p>5. On average, how long does it take for you to become operational? Is the time the same for all emergencies, or does it vary? If a similar emergency occurred in that area in previous years, does that help (for instance, do you already have local contacts)?</p>
 <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE	<p>6. Do you collaborate with other organizations (humanitarian or otherwise)? If yes, in which part of the supply chain?</p> <p style="text-align: center;"><b>SEZIONE 2: SUPPLY CHAIN DESIGN</b></p> <p><i>Questa sezione si concentra sulle strategie di disegno e organizzazione della supply chain, considerando modelli, posizionamento dei magazzini e scelte di distribuzione.</i></p> <p>7. Do you believe you apply a pull, push, or push-pull strategy?</p> <p>8. Where would you position yourselves within the Lee Matrix? (Lean, Risk Hedging, Responsive, Agile)</p> <p>9. Is the number of echelons (levels) in the supply chain always the same, or does it vary from one emergency to another?</p>

<p> <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE</p>	<table border="1"> <tr> <td data-bbox="338 1245 464 1944"> <p>14. In some cases, do you use intermodal transportation?</p> </td> </tr> <tr> <td data-bbox="464 1245 630 1944"> <p>15. How do you manage the last-mile strategy?</p> </td> </tr> <tr> <td data-bbox="630 1245 817 1944"> <p><b>SECTION 3: WAREHOUSE MANAGEMENT</b> <i>This section analyzes storage and handling methods, replenishment strategies, and inventory management.</i></p> </td> </tr> <tr> <td data-bbox="817 1245 1023 1944"> <p>16. Do you have a typical warehouse layout? For example, how do you arrange the different areas (order receiving, dry storage area, fresh storage area, sorting area, packaging area, loading area, unloading area)?</p> </td> </tr> <tr> <td data-bbox="1023 1245 1278 1944"> <p>17. Do you generally prefer small or large warehouses?</p> </td> </tr> </table>	<p>14. In some cases, do you use intermodal transportation?</p>	<p>15. How do you manage the last-mile strategy?</p>	<p><b>SECTION 3: WAREHOUSE MANAGEMENT</b> <i>This section analyzes storage and handling methods, replenishment strategies, and inventory management.</i></p>	<p>16. Do you have a typical warehouse layout? For example, how do you arrange the different areas (order receiving, dry storage area, fresh storage area, sorting area, packaging area, loading area, unloading area)?</p>	<p>17. Do you generally prefer small or large warehouses?</p>
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<p> <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE</p>	<table border="1"> <tr> <td data-bbox="338 374 544 1072"> <p>10. How do you choose the locations of your warehouses? Do you use specific models (e.g., Center of Gravity, Linear Programming)? Do you use specific tools? Do you rely on the experience of your logistics team?</p> </td> </tr> <tr> <td data-bbox="544 374 724 1072"> <p>11. What factors determine the choice of locations? What are the main criteria you consider?</p> </td> </tr> <tr> <td data-bbox="724 374 927 1072"> <p>12. How do you choose the distribution strategy (e.g., Warehousing, Cross Docking, Transshipment)? Do you always use the same strategy, or does it depend on the emergency?</p> </td> </tr> <tr> <td data-bbox="927 374 1230 1072"> <p>13. Which modes of transportation do you use (air, rail, road)? Do you always use the same modes, or does it depend?</p> </td> </tr> </table>	<p>10. How do you choose the locations of your warehouses? Do you use specific models (e.g., Center of Gravity, Linear Programming)? Do you use specific tools? Do you rely on the experience of your logistics team?</p>	<p>11. What factors determine the choice of locations? What are the main criteria you consider?</p>	<p>12. How do you choose the distribution strategy (e.g., Warehousing, Cross Docking, Transshipment)? Do you always use the same strategy, or does it depend on the emergency?</p>	<p>13. Which modes of transportation do you use (air, rail, road)? Do you always use the same modes, or does it depend?</p>	
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 <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE	<p>23. Do you use Kanban in the warehouse? If yes, how?</p> <p>24. Do you utilize safety stocks?</p> <p>25. Do you estimate a service level for your warehouses? Do you accept stock-outs or do you aim to avoid them?</p> <p>26. Do you have any form of packaging standardization?</p>
 <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE	<p>18. What kind of handling equipment do you use in your warehouses?</p> <p>19. Do you use FIFO or LIFO policies?</p> <p>20. Which of the following storage techniques do you generally use? (Drive-in racks, Drive-through racks, Block stacking, Cantilever racks, Selective racks)</p> <p>21. How do you determine stock levels in your warehouses?</p> <p>22. How do you replenish your stocks? Do you apply an ROP (Reorder Point) or PRM (Periodic Review) strategy?</p>

<div style="background-color: #002060; color: white; padding: 5px; text-align: center;"> <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE         </div> <div style="text-align: center;"> <h3>SECTION 4: INFORMATION ABOUT SUPPLIERS</h3> <p><i>This section aims to understand the relationship with suppliers, supply chain visibility, and supplier selection criteria.</i></p> </div> <div style="border: 1px solid #ccc; padding: 5px; margin-bottom: 10px;"> <p>27. Where would you position your supply chain visibility line? Do you believe it is important to track your suppliers? (For example, knowing that the wheat you bring to the Congo, where there is ongoing conflict, comes from an area prone to periodic drought.)</p> </div> <div style="border: 1px solid #ccc; padding: 5px; margin-bottom: 10px;"> <p>28. How do you choose your suppliers?</p> </div>	<div style="background-color: #002060; color: white; padding: 5px; text-align: center;"> <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE         </div> <div style="text-align: center;"> <h3>SECTION 5: INDICATORS AND KPIS</h3> <p><i>This section examines how information on emergencies is collected and evaluated, and how supply chain performance is monitored.</i></p> </div> <div style="border: 1px solid #ccc; padding: 5px; margin-bottom: 10px;"> <p>29. How do you collect information about emergencies?</p> </div> <div style="border: 1px solid #ccc; padding: 5px;"> <p>30. How do you assess the condition of infrastructures at the beginning of an emergency? How do you evaluate them during the emergency? Are you aware of the Logistic Cluster (and if so, do you use their information)?</p> </div>
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<div style="text-align: center;"> <p>9</p> </div>	<div style="text-align: center;"> <p>8</p> </div>



### SECTION 7: SUSTAINABILITY AND RESILIENCE

Here we explore the organization's focus on environmental and social sustainability, as well as operational resilience.

38. Is sustainability important to you?


39. Do you adopt any sustainable practices?


40. Do you consider yourselves resilient? Do you have a business continuity plan?




### SECTION 6: RISK ASSESSMENT

This section explores how the organization evaluates and mitigates potential risks and threats, including conflict scenarios.

34. What do you consider to be the possible threats associated with your work?


35. Do you use any model for threat assessment?


36. How do you manage these threats? (Risk mitigation practices)


37. In the event of a conflict, how do you ensure your security?


## SEZIONE 8: CASE STUDIES


Do you have information regarding:

- Number of supply chain levels
- Location of warehouses
- Modes of transportation
- Stock levels
- Stock replenishment system
- Safety stock
- KPIs
- Methods of performance measurement
- Risk management (risk assessment)

related to the following cases (or cases from 2016 to today that presented complex logistics):

- Flooding in Nigeria (2022)
- Pakistan Floods (2022)
- Russian Ukrainian War
- Democratic Republic of Congo
- Nepal Earthquake (2015)
- Türkiye Earthquake (2023)

## A.2. HSC Survey Model - First Round

 <b>POLITECNICO MILANO 1863</b>   DIPARTIMENTO DI INGEGNERIA GESTIONALE	
<h3>Survey on Critical Factors Influencing Humanitarian Supply Chain</h3>	
<p>This document presents the first round of a two-round Delphi-style survey designed to identify and evaluate critical factors influencing humanitarian supply chains. The first round aims to gather broad expert input, which will be synthesized and shared in a second round to refine consensus and prioritize the most significant variables. By rating each factor based on their importance and providing illustrative examples, experts will help in identifying areas that require strategic focus and improvements. Additionally, detailed explanations, practical experiences, or examples highlighting the relevance of each factor are highly encouraged.</p>	
<p>Participants are kindly requested to evaluate each factor listed below using the following 10-point scale:</p>	
<ol style="list-style-type: none"> <li>1. Not important at all</li> <li>2. Minimally Important.</li> <li>3. Slightly Important.</li> <li>4. Moderately Important.</li> <li>5. Important.</li> <li>6. Fairly Important.</li> <li>7. Very Important.</li> <li>8. Extremely Important.</li> <li>9. Critically Important.</li> <li>10. Most Important.</li> </ol>	
<p>Your contributions are vital in developing a comprehensive understanding of how these critical factors influence humanitarian supply chains and in formulating strategies to enhance the overall effectiveness and responsiveness of humanitarian aid delivery.</p>	
<p>For any clarification, please contact:</p> <ul style="list-style-type: none"> <li>• Mattia Longobardo (<a href="mailto:mattia.longobardo@mail.polimi.it">mattia.longobardo@mail.polimi.it</a>)</li> <li>• Matteo Schiattarella (<a href="mailto:matteo.schiattarella@mail.polimi.it">matteo.schiattarella@mail.polimi.it</a>)</li> </ul>	
<b>Data:</b>	
<b>Name and Surname:</b>	
<b>Organization:</b>	
<b>E-mail:</b>	
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<p> <b>POLITECNICO</b>   DIPARTIMENTO DI INGEGNERIA MILANO 1863   GESTIONALE</p>	<table border="1"> <tr> <td data-bbox="336 1245 520 1944"> <p><b>Comments:</b></p> </td> </tr> <tr> <td data-bbox="555 1245 876 1944"> <p><b>Climate</b> Local climate conditions, weather variability, environmental hazards, seasonal shifts, and climate-induced events such as flooding or droughts influence operational timelines, logistical planning, resource allocation, and staff preparedness.</p> <p><b>Score:</b></p> <p><b>Comments:</b></p> </td> </tr> <tr> <td data-bbox="911 1245 1232 1944"> <p><b>Politics</b> Political stability, strength of governance structures, regulatory frameworks, administrative efficiency, corruption levels, and diplomatic relations profoundly affect humanitarian access, operational constraints, security, and international cooperation.</p> <p><b>Score:</b></p> <p><b>Comments:</b></p> </td> </tr> </table>	<p><b>Comments:</b></p>	<p><b>Climate</b> Local climate conditions, weather variability, environmental hazards, seasonal shifts, and climate-induced events such as flooding or droughts influence operational timelines, logistical planning, resource allocation, and staff preparedness.</p> <p><b>Score:</b></p> <p><b>Comments:</b></p>	<p><b>Politics</b> Political stability, strength of governance structures, regulatory frameworks, administrative efficiency, corruption levels, and diplomatic relations profoundly affect humanitarian access, operational constraints, security, and international cooperation.</p> <p><b>Score:</b></p> <p><b>Comments:</b></p>
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## List of Acronyms

Acronyms	Meaning
<b>Organizations</b>	
AA	Action Aid
DR	Direct Relief
EE	Emergency
ICRC	International Committee of Red Cross
IFRC	International Federation of Red Cross and Red Crescent
IRC	International Red Cross and Red Crescent
LC	Logistic Cluster
MSF	Médecins Sans Frontières
NGO	Non-Governmental Organizations
OX	Oxfam
WFP	World Food Program
<b>Logistic Elements</b>	
HA	Humanitarian Aid
HL	Humanitarian Logistics
HSC	Humanitarian Supply Chain
HSCM	Humanitarian Supply Chain Management
IDP	Internal Displaced People
LPI	Logistic Performance Index
SC	Supply Chain
SCM	Supply Chain Management



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First and foremost, we wish to extend our most sincere thanks to our advisor, Professor Andrea Sianesi. His expert guidance, the valuable information he shared, the contacts he provided for interviews, combined with his constant availability and cordiality, were fundamental for the writing of this thesis.

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The interviews and surveys completed with your staff provided a practical perspective and a level of depth that no other source could have offered. Your willingness to share daily challenges, operational strategies, and lessons learned in the field was the true lifeblood of this thesis. We hope that this study can, in some small way, help to highlight the extraordinary work you do every day to alleviate human suffering and save lives.

