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Humanitarian supply chain: an analysis of response operations to natural disasters

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This paper presents an analysis of the logistics processes adopted in response to six major natural disasters that occurred in the last decade: (i) the Mozambique flooding in 2000, (ii) the Pakistan earthquake in 2005, (iii) the Indian Ocean tsunami in 2006, (iv) the earthquake in Haiti in 2010, (v) the flood and landslide in the mountainous region of Rio de Janeiro, Brazil in 2010, and (vi) the earthquake and tsunami in Japan in 2011. Through the analysis of secondary data, the main practices, problems and challenges in these post-disaster humanitarian operations are identified. This study aims to understand the environment and circumstances in which these humanitarian operations occurred, assessing the main constraints encountered and the approaches adopted to ensure the supply of relief to victims of natural disasters. Finally, suggestions are proposed in order to improve the efficiency and success rate of the logistics process in other humanitarian response operations.

Keywords: *Humanitarian logistics, humanitarian response operations, natural disasters.*

1. Introduction

Natural events can be characterised as natural disasters when they occur in populated areas, causing the destruction of local infrastructure and population, and leading to a state of deprivation and suffering. In the last three decades, the occurrence of natural disasters has increased significantly.

Immediately after the occurrence of disasters, humanitarian operations are initiated with the intent to provide rapid assistance to victims in different ways, such as rescuing those who are wounded and/or stranded, collecting and disposing of corpses, allocating resources, providing food aid, shelter and medical care, and restoring access to remote locations. These disaster response operations are usually multi-faceted and involve governments, non-governmental

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organisations (NGOs), United Nations (UN) agencies, and military and private sector organisations.

International humanitarian organisations have a responsibility among three groups of stakeholders: (i) donors, (ii) beneficiaries, and (iii) the international community (Oloruntoba and Gray, 2006). The main concerns of these organisations focus on the distribution of funds by institutional donors, the reactive nature of funding, donors' objectives that undermine organisations to act freely and the growing pressure for accountability. However, little importance is given to crucial indirect services such as information systems, personnel training, disaster preparedness and supply chain management (Kovács and Spens, 2007; Oloruntoba and Gray, 2006; Van Wassenhove, 2006).

According to Moore et al. (2003), humanitarian action should be led by one of the actors in the scene, preferably by an actor who knows the business practices and academic theory of supply chain management. However, the individual goals of the various actors involved in humanitarian operations do not always work to integrate and coordinate efforts. Moreover, different management styles, administrative structures and complex relationships among these different organisations also complicate the implementation of effective strategies for the supply chain. On the other hand, delays in delivery or relief can cost lives. Therefore, efficiency in logistics is a key success factor in disaster response operations, because it ensures the smooth flow of goods and services in a complex supply chain (Thomas and Kopczack, 2007).

Considering the importance of logistics to the success of disaster response operations, this paper presents an analysis of the main logistics processes that were adopted in the distribution of relief supplies in six major international disasters that occurred in the last decade: (i) the Mozambique flooding in 2000, (ii) the Pakistan earthquake in 2005, (iii) the Indian Ocean tsunami in 2006, (iv) the earthquake in Haiti in 2010, (v) the flood and landslide in the mountainous region of Rio de Janeiro, Brazil in 2010, and (vi) the earthquake and tsunami in Japan in 2011.This study aims to understand the environment and circumstances in which these humanitarian operations occurred, assessing the main constraints encountered and the approaches adopted to ensure the supply of relief to victims of natural disasters. Although none of the events assessed here occurred in Europe, it is important to stress that the results and conclusions of this study can also be applied to humanitarian operations in response to natural events on the European continent, such as the earthquake in L'Aquila, Italy in 2009, and the floods that affected Central Europe in 2010 or Great Britain and Ireland in 2012. According to a report of the European Environmental Agency (2011), the number and impact of natural disasters in Europe increased from 1998 to 2009.

This paper is structured as follows: Section 2 describes the supply chain structure and operation in disaster relief. Section 3 presents the research methodology used. Through secondary data, an analysis is performed assessing the six disasters from the perspective of the aid distribution process (Section 4) and suggestions are presented for improving the effectiveness of the process when applied to other humanitarian operations (Section 5). Finally, Section 6 discusses the recommendations resulting from the qualitative analysis and Section 7 presents the final conclusions of the research.

2. Supply chain management in a humanitarian context

The humanitarian supply chain, much like a commercial supply chain, includes the following activities: the preparation, planning, procurement, transportation, storage, tracking and customs clearance of supplies (Thomas and Kopczack, 2007). One of the main differences between commercial and business supply chains is their foci. In commercial logistics, the focus is on the final consumer, who is the input source of funds for the entire chain. However, in the humanitarian case, the beneficiary rarely participates in a business transaction and has little

control over supplies. Humanitarian supply chains need to be flexible and able to respond quickly to unpredictable events effectively (which can be the difference between life and death) and efficiently (to treat a greater number of victims) under heavy budget constraints.

The basic mission of humanitarian supply chain management involves the delivery of products and/or services to the needy, whose immediate or long-term survival can depend on the efficient execution of the operational activities of logistics and the supply chain, including the crucial last fifty miles. According De La Torre et al. (2012), the main challenge of humanitarian supply chain management is to establish, with a minimal waste of resources, the flow of donations from different sources (national and international) which are not always useful, timely or appropriate, while relying on an overwhelming quantity of poor quality information.

There are numerous challenges and difficulties faced by supply chain management in humanitarian contexts, such as administrative and logistical bottlenecks due to poor infrastructure for receiving aid and the multiplicity of agencies and governments acting in a response operation (Van Wassenhove, 2006). According to Oloruntoba and Gray (2006), major difficulties in coordinating the humanitarian supply chain are related to: a) political interests and military forces of donor and recipient countries, b) the requirements of donors, and c) the lack of coordinated plans. In addition, Mileti (1999) considers the geographical dispersion and insufficient or inaccurate communication between field and humanitarian organisations' headquarters, as well as between different organisations, as important factors that complicate the coordination of relief operations.

3. Research methodology

The present paper considers that, regardless of the type of disaster (floods and landslides, earthquakes, hurricanes, tsunamis, etc.), it is possible to learn from the analysis of the different response operations, since they are situations in which the scarcity of time and resources, associated with a constantly changing scenario, make logistics operations even more difficult, requiring the application of specific decision-making and operational models. Therefore, this paper analyses the main aspects of six response operations to natural disasters in order to identify common procedures that should be followed in the distribution process of a humanitarian supply chain.

The paper analyses five response operations to international disasters and one response operation to a disaster in Brazil. The selection of the five international events was based on the extent of their impact – number of victims, number of casualties, area affected and mobilisation of resources and volunteers – as well as the available data and the similarity of operating conditions in the responses. A Brazilian disaster was also included for a comparative analysis of the international procedures to our local context. Therefore, the disaster with the largest number of casualties to have ever occurred in the country was selected.

The analysis used secondary data. Scientific papers and recognised publications describing the operating environment and decision making in response operations to disasters worldwide were evaluated, as well as sources of documentary evidence, such as websites, reports and news. For the analysis of the response operation to the disaster in the mountain region of Rio de Janeiro, as well as secondary data, primary data obtained from interviews with members of the Civil Defence and of the Brazilian Army were also used.

Given the descriptive and explanatory purpose of the proposed study, content analysis was used as a basic analytical research tool. Information was obtained through interviews, documents, scientific papers and publications in the media, and was grouped in the following categories for the analysis of each disaster response operation: (i) the disaster profile (type, region and population affected, as well as extent and impact of the disaster); (ii) operating conditions for humanitarian operations; (iii) the logistics process; and (iv) critical aspects of the response

operation. In the stage of information systematisation, data was selected, analysed and compared in depth between several sources. This information was consolidated, resulting in the research structure. The resultant material was analysed and interpreted according to the theory of humanitarian logistics. Thematic analysis was adopted to identify the best case procedures (positive) and points for improvement (problems) in the responses to the disasters studied here. In the following section, the analysis of the response operations to each natural disaster is presented.

4. Assessment of response operation to the natural disasters analysed

The main features of the events studied are shown in Table 1. These disasters are analysed here individually according to the categories presented in Section 3.

Table 1. Characteristics of the natural disasters studied

	Mozambique 2000	Indian Ocean 2004	Pakistan 2005	Haiti 2010	Brazil 2011	Japan 2011
Type of disaster	Floods and cyclones	Earthquake and tsunami	Earthquake	Earthquake	Flood and landslide	Earthquakes and tsunami
Victims	2.04 million	1.7 million	3.5 million	2.0 million	90,000	402,069
Deaths	699	227,000	73,000	222,500	806	15,848
Affected area	Gaza, Inhambane, Manica, Maputo and Sofala	14 countries, but Indonesia, Siri Lanka, Maldives, India and Thailand were the most affected.	North Pakistan and Kashimir.	Port aux Prince, Leogane and Jacmel.	Petrópolis, Teresópolis and Nova Friburgo.	Tohoka and Hokkaido.
Impact	12% of Mozambican population was affected by the floods. 500,000 were homeless and placed in 100 camps.	Tsunami destroyed entire coastal shores, reaching even 3 km far from the coast.	30,000 km^2 of rough terrain in high altitude was affected, leaving over 200 million tons of debris.	75% of the buildings in Port aux Prince were destroyed or severely damaged, including the government headquarter.	It was the 10^{th} most severe landslide worldwide, affecting 20 cities and leaving 30,000 victims displaced.	Almost 500 km of coastal shore were affected, led to serious nuclear accident in Fukushima.

4.1 Flooding in Mozambique in 2000

In the first quarter of 2000, prolonged rains and the high-intensity cyclones Connie and Eline caused catastrophic flooding in five Mozambican provinces. The rain that fell during the rainy season of 1999-2000 was the largest amount in more than half a century, and the subsequent flooding reached record levels in 2000 (United Nations, 2000). The disaster affected approximately 27% of the population (Moore et al., 2003).

Operating conditions

For the first time the concept of a Joint Logistics Operations Centre (UNJLC) was used to manage and coordinate the air transport assets adopted in a response to natural disasters. The focus of the response was on rescue operations and providing food, water, shelter and health care to those left homeless due to floods (SIPRI, 2008).

The UN absence and the disease that attacked the Mozambican Minister responsible for government coordination during this disaster weakened the decision-making structure. The

INGC (National Institute of Disaster Management) was not prepared for the international assistance. According to Kehler (2004), several foreign military and international NGOs provided the INGC with very little indication of the type of assistance that would be provided or when it would arrive. A major consequence of this was poor coordination in the field.

With major roads inaccessible, most relief efforts occurred by air (DeBrouwer, 2000). However, South Africa was the only country from which Mozambique specifically requested military support; it sent a fleet of six helicopters and four planes, the only ones available in time for the initial operations of search and rescue. It is important to notice that for the first time the US Air Force (USAF) agreed to act under the direction of a civil society organisation (JLOC), actively collaborating for a coordinated response. The water operations were also successful, with boats being widely used to rescue people.

Logistics process
The creation of an emergency airstrip near the most affected regions reduced the number of flight hours and the distances travelled, relieving airport congestion, and allowing access to locations isolated due to damaged roads and railways.

The use of large-capacity bladders for fuel storage, as well as the use of Canadian Buffalo aircraft (highly autonomous), increased both storage conditions and freight capacity.

The distribution of hygiene and other essential items to camps was managed and coordinated by local authorities in conjunction with NGOs in the fields of housing structured according to the location of the homeless (Simkin and Gottwals, 2000).

Critical aspects of the operation
According to Moore et al. (2003), the major disruptions occurred in aid distribution (with five recorded deaths) and were caused by a lack of coordination among international NGOs, which encouraged victims to return to their homes in places still flooded. Moore et al. (2003) consider that the NGOs which most contributed to the distribution of aid in the response operation were those already based in Mozambique, because they already knew the area and population characteristics.

4.2 Indian Ocean Earthquake in 2004
In December 2004, a massive earthquake off Sumatra's northwest coast generated a tsunami that affected 14 countries around the Indian Ocean (Indonesia, Sri Lanka, Maldives and Thailand were the hardest hit). Entire coastal areas were destroyed, about 227,000 people were killed and almost 1.7 million were left homeless.

While parts of Indonesia were hit in a 20-minute period, other countries took several hours to be hit, leading to the conclusion that more extensive knowledge about the nature of tsunamis and an alert system and/or systems to communicate warnings could have saved many lives.

An intense media operation resulted in an overall response of 13.5 billion US dollars in aid to meet an estimated cost of 9 billion US dollars in damages and losses throughout the affected region (50% in Indonesia: Telford and Cosgrave, 2006).

Operating conditions
According to Telford and Cosgrave (2006), in all affected countries children were back to school quickly, and health facilities and services were restored efficiently and, in some cases, with significant improvement. Therefore, after a few months, there was evidence of a return to adequate living conditions.

The major constraints faced by the response operations in the affected regions were: the armed conflict in Sri Lanka and Indonesia; the corruption and distrust of local leaders; the quantity and

quality of international agencies' staff; inadequate methods and tools; and little engagement in management or coordination. The large number of international agencies and their insistence on separate programmes also led to a fragmented and ineffective humanitarian response.

Logistics process

The military played a major role in this disaster response, especially due to the restriction on air transport capacity. However, due to record funding from international sources, typical financial restrictions on humanitarian action were not a problem for the present case (Sphere Project, 2004). Slow and inaccurate prediction assessments and decision-making processes were characterised as the main restrictions for the success of the operation. For instance, three estimation methods indicated the existence of 700,000 people needing help in Indonesia in January 2005, but the World Food Program (WFP) budget was estimated to feed a million people every month for six months (Telford and Cosgrave, 2006).

The simultaneous coordination of a large number of actors and their diversity led to a more expensive and less effective response operation. Furthermore, the large amount of funding available reduced the motivation of the organisations involved to achieve a more efficient operation. The excess of unnecessary and inadequate donations also led to losses of time and resources (equipment and personnel) in an overloaded supply chain (Christoplos, 2006).

Nonetheless, other problems regarding logistics management and supply distribution were also faced in the operation. The total amount of supplies to be distributed burdened many international, national and local agencies. In the absence of complete lists of both goods and victims, the distribution was often performed randomly. The immediate consequences were: (i) clogged airports; (ii) piles of abandoned clothing donations (IFRC, 2009); (iii) vehicles and containers blocking access to ports and customs areas (Jakarta Post, 2006); (iv) 44 warehouses crammed with expensive materials and equipment deteriorating (Belawan, 2005); (v) inadequate supplies and lack of human resources to deal with the problem; and (vi) the loss, theft or sale of donations (Gunawan, 2005).

Despite the complexity of the logistics process, the LSS (UN Logistics Support System) was not used. The LSS is a modified version of SUMA – System Supply Management – designed to simplify key tasks of coordination, improving transparency in the management of humanitarian supplies, besides generating reports that can be shared among donors, local, humanitarian agencies and the media.

The local population, with private, public and/or military funds, started almost every operation of rescue and emergency support, followed later by international support. Affected communities themselves launched the first aid after the tsunami, and the teams were formed spontaneously. Private and public vehicles and boats, offices, schools and churches became readily available. Local stores provided food until foreign aid arrived about 3 to 5 days later (Scheper et al., 2006). Private companies like Rolls-Royce, Coca Cola and the Indian group Tata participated in the tsunami response.

Due to the poor quality of surveys, which did not record the number of serious injuries, the availability of medical personnel and resources or hospital capacity, it was not possible to monitor the effectiveness of the medical aid, or even to record the occurrence of mortality after the tsunami, especially in Indonesia and Sri Lanka (Goyet and Morinière, 2006). Most evaluations were conducted for the needs of particular agencies, rarely influencing decision makers collectively. Forecasting of needs carried out by the international community was based on data from national and local sources of such a poor quality that attaining a big picture of the situation was not possible; this shows that the international response was not sufficiently based in evidence (Goyet and Morinière, 2006).

Critical aspects of the operation

Many victims received more supplies than ever expected, to the point of selling the surplus (Goyet and Morinière, 2006), indicating that the division of goods to be distributed was not impartial or fair. Inequalities in aid were evident among the countries affected by the tsunami, within the countries, and sectorally, geographically and socially. Errors and inappropriate attitudes, though less visible during the relief phase, were present at all stages. As an example, meals containing pork were donated for Muslims in Aceh. It is considered that the excess funding in the tsunami response served as a lens to highlight problems in the humanitarian community.

4.3 Earthquake in Pakistan between 2005 and 2006

In October 2005, an earthquake measuring 7.6 on the Richter scale struck northern Pakistan and Indian Kashmir, killing 73,000 people and leaving many homeless (Tulloch, 2006). The devastation hit an area of 30,000 square miles of rugged terrain in regions of high altitudes, creating 200 million tons of debris, causing the destruction of most of the educational institutions and the collapse of health facilities and hospitals (Khan, 2006). Moreover, given the concern about the upcoming winter, the main challenges faced immediately after the disaster concerned the prioritisation of different aspects of the response: rescuing the injured and removing the dead, rapidly deploying forces, reaching remote locations that were difficult to access and providing shelter, food and medicines immediately.

Operating conditions

To manage operations, the Pakistani government centralised coordination and monitoring efforts in a Federal Commissioner (FRC) reporting to the Prime Minister. All agencies involved in aid and rehabilitation efforts (health, interior, foreign affairs, information and communication) were to act through the FRC. The FRC has a military branch responsible for rescue and help, and a civil branch addressing the issues between departments and agencies (Khan, 2006).

Despite the mechanisms provided by local government, several agencies acted with some autonomy in demand forecasting, procurement, distribution and recording, resulting in the unavailability of data. Approximately 90 agencies requested the UNJLC to coordinate their freight transportation. Lack of funds and difficulties in accessibility and in the acquisition process of aid supplies also represented major restrictions to the operation.

A number of aid activities needed to be put into practice immediately and simultaneously, such as casualty evacuation, damage control, medical aid and supply of relief goods (Khan, 2006). For such activities, transport capacity was one of the major constraints, limiting mainly the distribution process. National and international agencies aggressively used both road and air transportation (mainly by helicopter) for distribution of aid and of equipment for reconstruction. Other restrictions were associated with fundraising, demand forecasting and the acquisition of supplies.

Logistics process

The Pakistani government organised the response operation according to four strategic groups, of which the FRC was responsible for two: search, rescue and support, and results management.

According to Khan (2006), supply distribution was the result of frequent and numerous decisions, using cognitive models to face many difficult choices, and considering the importance of knowledge of the affected region, as well as the characteristics of the conflict in Kashmir and the rigour of the coming winter. Eight decision variables were used in this decision-making process: three related to the needs of the affected population (population affected, level of destruction and pre-existing poverty in the affected region) and five associated with the conditions of the logistics operations (historical requests, transport capacity, accessible roads, geography, and distance to the central deposit).

Critical aspects of the operation

One of the issues that caused concern was the existence of "exclusion policies" to benefit victims of humanitarian action. Such exclusion policies are always accompanied by significant flaws in contingency planning (Waters, 2001). In this particular event, the exclusion did not occur just by rating the needy, but some areas were not considered by the model used to plan the supply distribution, resulting in five regions that did not receive the three main groups of supplies: (i) food and water, (ii) shelter and clothing and (iii) building materials and construction tools.

Other critical aspects of the operation were the lack of a full-time operations manager after the disaster and the lack of appropriate mechanisms to track and control the aid flows from source to final user. Khan (2006), Tulloch (2006) and Benini et al. (2008) consider that proper management of these issues could have made the response action to the disaster more efficient and effective.

4.4 Earthquake in Haiti in 2010

The earthquake (level 7 on the Richter scale) that struck Haiti in 2010 killed 200,000 people, injured 300,000 and left over a million homeless. With its epicentre just 10 miles below the surface and near the urban centres of Leogane, Port au Prince and Jacmel, the earthquake was the most powerful that the country had experienced in 200 years. In addition, it must be considered that Haiti has a history of weak government institutions that hindered risk reduction and response efforts in the country.

The capital Port au Prince was severely hit and national command centres were destroyed with high human loss in the administration. Likewise, the UN Stabilisation Mission in Haiti (MINUSTAH) lost some of its leaders, partially paralysing its activity (Grünewald and Renaudin, 2010).

Operating conditions

About 75% of the buildings in Port au Prince were destroyed or seriously damaged after the earthquake. In response to this catastrophe, a relief and recovery operation was started by a complex set of national and international actors. The main challenges and restrictions faced in such operations were: lack of equipment for search and rescue, limited availability of equipment or transport routes to transfer victims, lack of medical facilities, serious problems in the communication network and government institutions seriously affected. In addition, MINUSTAH lost their leader, the General Secretary, and many of his managers.

During the first days after the earthquake, access to food, water and shelter was extremely problematic. As aid was slow to arrive and local conditions were difficult, thousands of victims followed the government's advice and left the capital for the rural areas and small towns that were not directly affected by the earthquake or where they had family.

Due to difficult conditions in the country, many teams had difficulty finding transportation. Many cars were destroyed or blocked by debris from collapsed buildings and it was very difficult to obtain fuel during the first few days. In addition, although the airstrip was not affected and could be used even by large freighters, the airport was not easily accessible except for pilots able to make landings without control tower support. During the first three days of response, the number of flights increased from 13 to 100 per day and after the fourth day of operations, aircraft waiting to land became a problem.

The capital harbour, due to damage caused by the earthquake, was not accessible. Military vessels that were mobilised could not access the pier to unload their cargo of food and other donations. A solution was the use of amphibious ships which enabled the rapid unloading of goods on the beaches, bringing among other things, vehicles that were lacking during the first days.

Logistics process

During the initial food distribution, the situation became chaotic due to poor preparation. The food distribution from the back of trucks or launched from helicopters and parachutes was disastrous, creating the feeling that humanitarian action would be very difficult.

There were also considerable problems in accessing the affected neighbourhoods, especially due to the urban characteristics of the city (densely populated slopes that lead to small coastal plains). The roads leading to the city from the port, airport and the Dominican Republic were partially blocked.

The logistics cluster helped in the delivery of relief supplies with a fleet of trucks managed by Handicap International/Atlas. Until October 2010, 46,500 m^3 of relief goods were dispatched from Port au Prince to the affected sites (90% by land and 10% by air). Also 1,300 trucks were dispatched from Santo Domingo to Haiti, delivering over 35,000 m^3 of supplies. Innumerable assessment missions were performed by helicopters and 3,100 m^3 of items were delivered, especially medicine, food and shelter for 48 different locations.

To meet the storage requirements, an area of 20,000 m^2 for storage/transit was created amidst the capital as a central point for organisations to create and manage their own mobile storage units (MSUs). By the end of March 2010, this deposit was transferred to Tabarre, where the same services were performed in an area of over 3,000 m^2. At the end of 2010, the logistics cluster organised 24 mobile storage units sent to Port au Prince from the United Nations Humanitarian Response Depot (UNHRD) in Panama; these were used by various organisations as Cholera Treatment Centres.

The evaluation of the situation and demand forecasting were difficult and complex. Although, during the first days, satellite imagery and new mechanisms for sending images played a key role, this soon became difficult when the available frequencies rapidly saturated, requiring field assessments without enough helicopters to meet the demand.

Critical Aspects of the Operation

The original measures adopted by the UN aimed at the safety of storage centres and the distribution process, making access to the field slower, and complicating the assessment of needs and the humanitarian action. Due to severe shortages and delays in the arrival of help, relief camps were created. The creation of such camps can be practical in terms of logistics but can also lead to violence when people feel frustrated and deprived of their basic needs.

The military played a dominant role in the operation. A system of food distribution was created at 16 sites under the control of MINUSTAH and the US Army; from these sites WFP and United States Agency for International Development (USAID) and their partners performed the distribution. On the other hand, distribution without military escort was conducted by various NGOs, which were believed to be better at working closely with communities and applying a form of social engineering to distributions. According to Holguin-Veras (2010), this represented two models of a supply network adopted simultaneously: Collaborative Networks (bases using existing social networking sites) and Focussed Efforts in Agencies (using operational centres which concentrate all warehousing and distribution).

In a situation of acute crisis, it is important to receive information quickly, even if it is only moderately reliable, instead of having accurate information provided too late. Data was collected according to complex protocols aimed at statistical representativeness, and was then processed and analysed. Therefore, due to the speed with which the scenario changed, such data often ended up losing some of its relevance and validity, and by the time the report was available, the data was usually obsolete. The quality of the donations was also a problem for the humanitarian supply chain. Several cases of inappropriate materials overloading the logistics flow were reported.

4.5 Flood and Landslide in Brazil in 2011

In January 2011, the mountainous region of the State of Rio de Janeiro was hit by a flood followed by a landslide (the largest in the country's history and the eighth worst landslide in the world over the last decade: EM-DAT, 2010), killing 916 victims and leaving 30,000 homeless.

Operating conditions

The initial actions immediately after the disaster faced serious restrictions, such as: (i) a lack of information about the real dimensions of the catastrophe, (ii) looting and insecurity in some affected locations, (iii) a lack of adequate transportation for the operation, (iv) difficulties in the use of the available communication system due to region topography, (v) the poor quality of available local maps, (vi) a lack of adequate floating equipment, and (vii) destruction of the access to affected areas. Under these conditions, the following activities were prioritised while beginning the response operation: a) the establishment of communication with the affected areas, b) aerial and ground reconnaissance, c) the rescue of survivors, and d) cleaning debris and restoring access roads.

The operations initially carried out by the military involved clearing debris to allow access to isolated areas, and search and rescue operations (persons and corpses). Later, the military also participated in receiving, sorting and distributing donations, in gas distribution, in loading and unloading trucks of donations, in transporting donations, in distributing water and in traffic control.

The reduced number of vehicles suited to the ground conditions and the unavailability of ferries and boats prevented immediate action at certain times. However, the use of helicopters (from the military) was critical to the success of the operation.

Logistics process

Access to the mountain region of Rio de Janeiro is by road. The main access roads are BR 040, BR 116, BR 101 and RJ 116. Due to landslides, these roads were partially blocked with access restored after a few days after the flood being the access released a few days after the flood. However, several routes within cities were blocked due to landslides that isolated communities. A month after the disaster, access to all areas was restored. The Brazilian Army had an important role in clearing debris and unblocking roads. This action was essential to allow access for relief operations, the rescue of victims and the distribution of supplies.

Traffic control was necessary to access restricted areas and to meet the great demand for the distribution of supplies and services. After all, there was a large volume of donations that were much needed by victims. The transport of donations from other regions of Brazil to Rio de Janeiro was conducted by the Air Force, which provided aircraft, trucks and trailers.

However, the processes of receiving, sorting and delivering donations had a lower performance level. Displaced and homeless victims were mostly sheltered in public schools, but managing these shelters (70 in total) was complex, mainly due to the lack of specialised personnel.

The difficulty of communication via radio equipment (available from the Armed Forces) due to the local geography led to the use of satellite equipment. Local telephone companies provided resources and equipment that helped increase the performance of communications.

Critical aspects of the operation

Despite the dedication and resilience of field teams, the operation faced serious problems of planning and logistics, such as lack of guidance and equipment for teams arriving at affected locations just after the disaster.

The main actors involved in this humanitarian operation were the state government, local governments of the affected cities, the Civil Defence of the State of Rio de Janeiro, the National

Security Force, the Fire Brigade of the State of Rio de Janeiro, military forces and NGOs. However, on the first two days, their actions were not coordinated and, in some situations, there was overlapping of efforts to respond to the same problem. The guideline of the Institutional Security Office indicated that local governments should coordinate their actions through Crises Management Centres, which were responsible for establishing collaboration among the different actors and their actions.

The distribution of donations was to be undertaken by the Armed Forces following the plan established by the Crisis Management Centres. However, due to a lack of information, the difficulty of radio communication and low-skilled field personnel, such planning was flawed and supply distribution was performed in an almost random manner. Problems were observed in the logistic support for operational activities (such as fuel and food distribution).

The use of helicopters in rescue operations and in supply distribution was essential during the first days of operation. Nonetheless, the number of helicopters available to meet the demand was a restriction. Thus, planning the use of helicopters to carry out supply transportation and rescue injured and homeless victims is a potential research topic, since there is need for improvement in such operations.

4.6 Earthquake and Tsunami in Japan in 2011

In March 2011, a 9.0 earthquake on the Richter scale hit the east coast region of Japan. The earthquake was so strong that it moved Honshu, the largest island of Japan, 2.4 metres to the east and shifted the Earth on its axis about 10 to 25 cm.

Operating conditions

In total, 269 fires and 60 landslides were reported, 3,562 buildings were destroyed and telephone services remained unstable. The Japanese national health system was severely affected. In some areas, response command centres were destroyed and health professionals became victims. According to initial reports, 145 of 170 hospitals designated to respond to disasters in Tokyo and Tohoku were operational on the first day after the disaster. Given the scenario, the Health Ministry initiated the following response actions: (i) coordinating the logistics of medical supplies and equipment; (ii) supporting local governments in collecting the corpses, including the distribution of dry ice for preserving corpses for funeral services; and (iii) counselling local governments about the risks of food poisoning, infectious disease and deep vein thrombosis.

Search and rescue operations employed military and private ships, Air Force fighters (for reconnaissance) and Army helicopters. Within two days after the incident, 3,000 victims were rescued. Simultaneously, the Coast Guard coordinated the evacuation and alert services, including warnings about potential exposure to radiation at the nuclear plant in Fukushima. Likewise, the Japan Self-Defence Force (SDF) conducted search and rescue operations, and delivered basic supplies.

All Japanese ports were briefly closed after the earthquake. Fourteen major ports in the Tohoku region became non-operational; sections of national and provincial roads were closed. The SDF unblocked most of the roads just three days after the catastrophe, which significantly helped to improve the performance of emergency operations.

Logistics process

Municipal governments in Japan hold the exclusive right to stock and distribute relief supplies in response to disasters. However, the wide dispersion of the people affected by the disaster and the destruction of municipal and individual records in the affected communities, in addition to the loss of municipal employees, affected their ability to distribute funds for emergency actions.

Temporary housing units, designed to accommodate victims for 2 or more years, in Iwate and Miyagi contributed to reducing the number of victims in evacuation centres. In order to avoid the

impact of continuous changes in the need for supplies due to the constant change in the demography of the evacuees, initiatives to centralise information were taken, aiming at better fitting the supply to the demand. In this effort, the Civil Force established a list of 119 food items. This list was the result of research developed in the affected areas. This action helped in delivering the right goods to the right shelters just 2 weeks after the incident. In addition, five third-party logistics providers offered their services to the authorities, which, according to Holguín-Veras (2011), helped prevent a massive humanitarian crisis.

Critical aspects of the operation

All government agencies and municipalities had disaster response plans and conducted annual training, but they did not simulate humanitarian logistics operations, because they believed that they would know what to do in real time, which did not necessarily turn out to be true and ended up leading to delays in supply delivery.

An important conclusion for the proper functioning of shelters is that small centres seemed to work best due to the possibility of better interpersonal relationships and greater privacy. Another important observation regarding the distribution centres was made by Holguín-Veras (2011), who verified that 40% of the supplies being transported were clothing items that were hardly used for victims but consumed almost a third of the efforts of the operating personnel working in the distribution centres.

5. Comparative assessment of the response operations

Through the assessment of the response operations to the natural disasters analysed in the present paper, several problems could be observed in preparing and conducting humanitarian logistics processes. Even when there was prior planning, as in the case of Japan, lack of training in logistics operations caused delays at the beginning of the response aid. Such negative points can be considered opportunities for improvement, and can therefore be considered relevant topics of research. On the other hand, the positive aspects observed in these operations can be considered the best practices. These successful cases should also be the basis for further analysis considering future application in humanitarian operations. Content analysis, more precisely thematic analysis, was developed in order to identify such opportunities for improvement (problems) and best practices (positive). Table 2 summarises the results of this phase of the research.

Table 2. Research topics in the field of humanitarian logistics

	Opportunities for improvement	Best practices
Mozambique (2000)	1. Problem on the decision-making process. 2. Coordination problems and duplicated activities. 3. Problems in food distribution. 4. Problems on data collection.	1. It was the first time that UNJLOC planned and coordinated air transport. 2. Intensive use of helicopters. 3. Use of military logistics techniques in planning air transport.
Indian Ocean (2004)	1. Coordination problems. 2. Lack of trained staff. 3. High costs of military operations. 4. Excess of unnecessary or inadequate donations. 5. Poor data collection. 6. No performance indicators saved for analysis.	1. Military had a key role in the operation. 2. No financial restrictions on humanitarian action due to a record on international funding.
Pakistan (2005)	1. Problems with funding, demand forecasting and acquisition. 2. Flaws in the distribution model. 3. Lack of appropriate mechanisms of tracking and control of the aid flow.	1. Though presenting failures, a model for prioritizing and planning the aids distribution was developed. 2. Extensive use of helicopters.
Haiti (2010)	1. Problems with the affected area mapping and demand forecasting. 2. Shortage of transportation resources for aids distribution. 3. Coordination problems. 4. UN security system caused difficulties for operations. 5. Lack of skilled and experienced personnel. 6. Difficulty to collect data after disaster due to local conditions. 7. Excess of unnecessary donations. 8. Complex protocols for data collection. 9. Lack of equipment to clear debris.	1. Use of amphibious ships for food distribution and rescue operations. 2. Use of UN logistics clusters. 3. Intensive use of helicopters. 4. Military had a key role in the operations. 5. Distribution of aid kits for the victims, like "Ready to Eat Meals". 6. Use of satellite imagery. 7. Two different kinds of supply networks were applied.
Brazil (2011)	1. Coordination problems. 2. Lack of data and information of the affected areas. 3. Fuel and communication resources shortages. 4. Several logistics problems in the supply chain. 5. Management problems of homeless camps.	1. Military had a key role in the operations. 2. Intensive use of helicopters.
Japan (2011)	1. Excess of unnecessary or inadequate donations. 2. There were plans and training for disaster response except for logistics operations required.	1. Military had a key role in the operations. 2. The world's leading logistics companies helped in the aid distribution operations.

For a better understanding of the issues involved in humanitarian logistics, the opportunities for improvement (problems) and best practices (positive) presented in Table 2 were grouped according to the different stages of the humanitarian supply chain, as shown in Table 3. The model chosen to represent the different stages of the humanitarian supply chain is the one proposed by Thomas (2003), presented in Figure 1, which highlights the scope of this study.

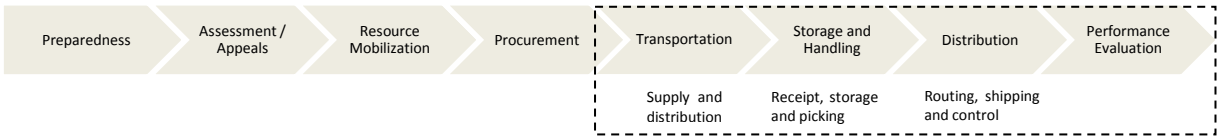

Figure 1. Scope of the study in humanitarian supply chain (Source: Adapted from Thomas (2003)).

Based on the structure of Figure 1, the opportunities for improvement (problems) and best practices (positive) presented in Table 2 were grouped according to the different stages of the humanitarian supply chain (Thomas, 2003) in order to facilitate an understanding of the key issues in disaster response operations, as shown in Table 3.

Table 3. Opportunities for improvement and research according to the stages of humanitarian logistics

Logistics process	Characteristics	Mozambique	Indian Ocean	Pakistan	Haiti	Brazil	Japan
Acquisition	1. Coordination	OI	BP		OI		
	2. Decision-making process	OI		OI			
	3. Quality/quantity of donations		OI		OI	OI	OI
	4. NGOs involvement	BP	OI				
	5. Demand forecasting		OI	OI	OI		
	6. International mobilization		BP	OI	BP		
	7. Data of affected areas		OI		OI	OI	
Storage/Handling	1. Use of UN JLOC	BP					
	2. Use of UN Logistics Cluster				BP		
	3. Evacuation camps				OI	OI	BP
	4. Quantity and experience of personnel		OI		OI		
	5. Readiness to action				OI		OI
Transport and Distribution	1. Capacity		OI	OI	OI		
	2. Distribution	OI		OI	BP		
	3. Military involvement		BP	OI	BP	BP	BP
	4. Control and monitoring of deliveries	OI		OI			
	5. Use of helicopters	BP		BP	BP	OI	
	6. Use of floating boats and dinghies	BP			BP	OI	
	7. Communication				OI	OI	

BP= Best Practice
OI= Opportunity for improvement

6. Recommendations based on the qualitative analysis

This section presents recommendations and proposes approaches to the opportunities for improvement and research identified in the comparative analysis (Section 5).

The comparative analysis of the response operations to the natural disasters analysed here identified that the first aid after a natural disaster is given by the local population, which spontaneously forms teams to work primarily in searching and rescuing, as well as supporting initial emergency relief. Therefore, training the population in areas susceptible to natural disasters becomes essential. Besides knowing how to protect themselves, where to get help and where to go in case of evacuation, local people should also be trained in how to offer help to other victims while the humanitarian operation is still being mobilised. This action would allow

for greater efficiency and safety in the aid provided by the local population. This type of training already occurs in countries such as Japan.

Another aspect observed in all cases studied is the large number of actors involved in such operations, as well as problems of coordination among them. In the case of the Indian Ocean tsunami, for example, the large number of international agencies and their insistence on the application of separate programmes led to a fragmented, more expensive and less effective operation. In Mozambique, NGOs acted without coordination, leading to major disruptions in supply distribution (with five deaths recorded), as they encouraged homeless people to return to their homes in places that remained inundated. Despite the dire need of help, it is important to control who is working in the operation and their responsibilities through a Crisis Management Centre, as was attempted in the disaster that occurred in the mountainous region of Rio de Janeiro. This centre should record and track all actors involved in the operation transaction, structuring an array of responsibilities.

Furthermore, in order to make the humanitarian operation clearer and more objective, a division of work between the actors involved in humanitarian operations should avoid duplication of efforts. The United Nations proposed a classification of humanitarian activities in 11 different *clusters* (agriculture, coordination and management, recovery education, emergency shelter, telecommunications, health, logistics, nutrition, protection, water and sanitation). This concept of *clusters* in humanitarian logistics has been applied to organising aid operations; thus, actors are classified by these clusters, facilitating the definition of roles and responsibilities. The mobilised groups in each cluster should cooperate in order to serve beneficiaries better, as occurred in Haiti in 2010 when the logistics cluster was triggered, facilitating deliveries of supplies and organising the storage of mobile units sent to Port au Prince from UNHRD in Panama.

Also with regard to the actors involved in response operations to natural disasters, the involvement of the military was common to all the events studied. Although the cost of military support is high (Borton et al., 1996), the Armed Forces have played an important role in disaster response operations (Apte, 2009). The capacity of NGOs is not always enough to respond to these massive and sudden events, so that rapid military support can be essential. After all, they have, ready for deployment, assets required for these operations, such as medical and fuel supplies and equipment for transportation, communications and engineering. Other military capabilities that can be applied in humanitarian operations are related to road construction, engineering and logistics. Therefore, the military should act in the immediate response phase of a humanitarian operation, but as soon as the crisis becomes stable, NGOs should take over the operation and remain on the scene throughout the reconstruction. The military should play only a supporting role in order to facilitate the process of the transfer of responsibilities from the military to NGOs. Consequently, it is important for governments to set clear and objective rules for how the military shall act in order to facilitate its action in responding to disasters.

The pre-positioning of military units in critical areas prone to disasters, as happens in Australia, is also a solution that can be adopted to accelerate military action, increasing responsiveness and reducing the cycle time of the operation. This solution also contributes to knowledge and experience transfer in humanitarian operations. The probability of military involvement in a response operation is high, but the designated personnel often have little experience in this type of action due to the frequent rotation of staff members. Therefore, lessons learned in one situation are rarely applied to the next crisis. The pre-positioning of military units can help to create an organisational structure that leads to the transfer of knowledge about the challenges faced in humanitarian operations.

Coordinating the action of actors with distinct organisational cultures, such as NGOs and the military who have ideological differences and negative organisational stereotypes, is complex (Tatham and Kovács, 2010), as noted in the discussions of the disasters that occurred in the Indian Ocean and Brazil. Due to the diffuse nature of the NGO community, the military often

have difficulties when trying to find out who is in charge, what organisational structure is presented in the country or how the chain of civil command works. Military officials also fear that if they improve their skills in this regard, they will be called upon to carry out humanitarian operations rather than engage in war and combat. In turn, the NGOs fear that the military want to take command and control of the operation.

Such fears and mistrust make the exchange of information among these actors even more difficult. Although NGOs are usually very open about information regarding the needs of victims, they are reluctant to share other information for fear that the military are interested in data that go far beyond the immediate crisis (Byman, 2001). Therefore, it is important to establish measures to ensure familiarity between the different actors involved in this type of operation in order to improve the exchange of information and facilitate long-term planning. Thus, it is important to conduct lectures and courses in military educational institutions, as well as conferences, in order to improve the general awareness of the capabilities and concerns of NGOs. Furthermore, in cases of disaster, the military should establish a temporary structure responsible for connecting with NGOs to collect and filter information, encouraging the exchange of information and coordination of procedures and priorities between NGOs and the military.

Another problem common to disaster response operations is inefficiency in identifying and communicating information about victims' needs, which is necessary data for defining the location of deposits and the delivery model to be practised. In fact, the collection and exchange of information are difficulties observed in all the cases analysed. Measures for centralising data collection, the pre-registering of information on residents of risk areas, the previous mapping of such areas and the application of techniques of information management can be applied to improve data collection and to make coordination more effective. These solutions should be associated with the development and application of information systems to support the process of collecting and exchanging data. An example of this is the LSS, which is responsible for coordinating the humanitarian supply chain, improving transparency, and creating reports shared among donors, local authorities, aid agencies and the media.

The use of modal alternatives to road transport (mainly helicopter) is another issue to be improved in the operational process of supply distribution, as problems with supply distribution were common to all the events analysed. One successful example occurred during the disaster in Mozambique, where the Joint Logistics Operations Centre managed and coordinated air transportation in the response operation. This was the first time that the US Air Force agreed to act under the direction of a civilian agency, with very positive results. Despite the large use of air transport in this relief operation, no accident occurred and measures which optimised the number of flight hours and reduced congestion at airports could be implemented. This example highlights the effective use of military vehicles in this type of operation, despite the high cost of operation for these devices.

As a result of the qualitative study, we could conclude that the humanitarian supply chains work as a push system, in which donations that do not meet victims' demands are pushed into the system, consuming scarce resources and increasing losses and waste. The sorting of donations, when performed, is done only at the end points of distribution, overloading storage units and transport with unnecessary items. This problem has been observed in humanitarian operations in both developing and developed countries, such as Japan. In consequence, it is essential to study the best chain structure to locate screening points where donations that do not fit the demand would be discarded to avoid congestion of an infrastructure already damaged by disaster.

The texts studied did not allow a clear identification of a distribution model that has played an effective role in more than one of the response operations. A centralised collection point through the use of camps presented problems with regard to security in Haiti (2010) and coordination in Brazil (2011), although there is mention of success in Japan (2011), probably due to training conducted prior to the event. Another successful practice employed in the operation of the

tsunami response in Japan (2011) was the distribution of supplies by logistics providers. It is believed that this practice can help to enhance efficiency in the distribution process, since logistics providers already have the knowledge and equipment necessary to operate even in the most adverse conditions, as well as specialised labour, which is often a serious problem faced by NGOs, which, in general, depend on the action of volunteers, who are often inexperienced and lacking in training.

Another problem observed after the earthquake in Haiti and the floods in Brazil were cases of looting and insecurity in some affected localities. Violence also occurred in New Orleans, USA after Hurricane Katrina. This type of behaviour tends to occur in operations with shortages and delays in the arrival of help, generating frustration and anger among victims. Thus, the importance of efficient logistics operations for the success of response aid is again evident. A practice that can also enhance the problem of violence is the allocation of homeless victims into camps. Despite being a practical solution in terms of logistics, these camps can lead to violence instead of providing support for security mechanisms, because frustrated people, deprived of their basic needs, can become violent. In the Japanese case (2011), a practice was observed that can contribute to solving this problem. It is the construction of temporary housing units (to be used for 2 or more years) instead of evacuation camps. However, it must be considered that the costs involved in this type of aid are much higher.

Finally, through the analysis of six major natural disasters, it could be concluded that, in the context of humanitarian logistics, decisions tend to be made under conditions of urgency and based on the experience of professionals involved in the response operations. The decision process for this type of operation is extremely complex, since important attributes of the problem are uncertain and demand changes rapidly. Besides, there is little time and information may not be available to make a decision (Beamon and Balchik, 2005). Therefore, in this type of situation, there is a tendency to use mental models for making decisions based on experience and intuition (Forrester, 1971), but mental models for decision making in this context are too complex to glimpse the whole operation, considering also the fact that human intuition and experience are affected by irrational factors, such as emotions and time pressure. As a result, the delay in decision making tends to affect, among other things, the efficiency of rescue teams to meet the needs of victims within requirements. Consequently, the application of mathematical models based on operations research techniques to aid the decision-making process in humanitarian logistics operations can contribute to its rationalisation, and hence improve the performance of humanitarian logistics in response operations to natural disasters.

Considering this context, we studied in the literature mathematical models based on operations research techniques which can be applied to solving the challenges of humanitarian logistics, although there is a limited amount of published work in this area. Perez et al. (2010) emphasise the small amount of material available. When researching applications of operations research in disaster management and operations, Clark and Culkin (2007) identified only 109 articles, of which only 31 are related to natural disasters.

During the research process, we could identify 44 articles that deal with the humanitarian logistics activities under the scope of this study (acquisition, storage and handling, transportation and distribution). Such articles were researched in academic databases such as Web of Science and Science Direct. Of these articles, 25 were selected for analysis because they are applications of mathematical models that analyse one or more opportunities for improvement and research in the humanitarian operations identified in Section 5. Therefore, we identified which models proposed by the 25 articles we analysed could be applied to help solve the major challenges encountered in humanitarian logistics operations (previously identified and presented in Table 3). Table 4 presents the main challenges faced in different humanitarian logistics activities and the articles that study such problems through mathematical models. However, some opportunities for improvement and research (Table 3) were not covered by the selected articles: (i) a few because such problems have no mathematical solution, requiring the detailing of

activities, roles, responsibilities, policies and procedures; and (ii) other topics that still need to be studied in future research.

Table 4. Articles related to opportunities for improvement in humanitarian logistics

Logistics activity	Logistical challenges	Models proposed
Acquisition/ Funding	Coordination	Özmadar *et al.* (2004)
	Decision-making process	*
	Quality and quantity of donations	Wyk *et al.* (2011); Emmelt and Londree (2011); Ozbay and Özgüven (2007); Balcik and Beamon (2008); Beamon and Kotleba (2006)
	Participation of NGOs	*
	Demand survey	*
	Information about the affected areas	*
Storage and Handling	JLOC concept application	**
	Clustering	Falasca *et al.* (2009); Jaller and Houlguin-Veras (2011); Balcik and Beamon (2008); Günnec and Salman (2007); Özdamar and Yi (2007);Falasca *et al.* (2009); Jaller and Houlguin-Veras (2011); Balcik and Beamon (2008); Günnec and Salman (2007); Özdamar and Yi (2007)
	Use of camps	
Distribution and Transportation	Capacity	Nagurney *et al.* (2012); Nagurney *et al.* (2010); Salmeron and Apte (2010); Clark and Culkin (2007); Balcik and Beamon (2005); Barbarosoglu and Arda (2004)
	Distribution	Huang *et al.* (2012); Lin *et al.* (2011); Lin *et al.* (2010); Perez *et al.* (2010); Lin *et al.* (2009); Campbell *et al.* (2008); Özmadar and Yi (2007); Özmadar *et al.* (2004)
	Military performance	Falasca *et al.* (2009)
	Control and tracking of deliveries	Falasca *et al.* (2009)
	Civil-military coordination	**
	Use of helicopters	**
	Use of boats and dinghies	**
	Communication	**

* Problems to approach through rules and procedures.
** Problems yet to be studied through the development of mathematical models.

It can be concluded from the study of mathematical models presented in Table 4 that there is still a gap between what is modelled and what actually occurs in the field of disaster response operations (in the real operational process). There are significant advances in the area, such as the inclusion of decision variables representing humanitarian aspects in the formulation of these models. However, what is not possible is a direct use of the proposed models in a real disaster response operation with the expectation that some of the identified problems could be effectively solved. It was identified that the proposed models seem scattered, with little synergy between the different proposals and their applications. Such models offer different alternatives, but they are not complementary and, with few exceptions, they have little understanding of the real conditions of a response operation. This is one of the main points that need to be improved in order to motivate operations managers to use mathematical models in the decision-making

process of humanitarian operations, rather than making decisions based on mental models or on human intuition and experience.

7. Conclusions

This paper presents an analysis of the main logistics processes that were adopted in the distribution of relief supplies in six major international disasters that occurred in the last decade: (i) the Mozambique flooding in 2000, (ii) the Pakistan earthquake in 2005, (iii) the Indian Ocean tsunami in 2006, (iv) the earthquake in Haiti in 2010, (v) the flood and landslide in the mountainous region of Rio de Janeiro, Brazil in 2010, and (vi) the earthquake and tsunami in Japan in 2011. This study assessed the environment and circumstances in which these humanitarian operations occurred in order to identify their main constraints and the approaches adopted to assure the supply of relief to the beneficiaries.

Results indicate that the application of concepts and techniques of military and commercial logistics in the humanitarian supply chain has limited effectiveness due to the complexity of a post-disaster scenario, in which there is a serious shortage of resources to handle the storage, transport and distribution processes. Besides, the number of beneficiaries and their needs and urgencies are directly related to the magnitude and impact caused by the disaster. Also, the quality and availability of supplies may not be enough to meet the needs of the beneficiaries, requiring allocation decisions which may cause delays that can result in suffering and cost lives.

Therefore, it is important to understand the dynamics of natural disasters, as well as analysing the adequacy of available techniques from commercial and military logistics for the circumstances and priorities of humanitarian operations. In this context, the present study enabled the observation of the occurrence of common logistical problems in the humanitarian supply chain, regardless of the type of disaster. Moreover, successful actions in certain relief operations are often not replicated in other humanitarian efforts in response to new disasters, and mathematical models are not adopted for optimising the distribution process of such operations. As a result, a succession of losses and waste of scarce resources is typical.

The present study shows different opportunities to improve response operations to natural disasters which can be addressed by future research. The analysis indicates the following factors as the major challenges faced in humanitarian logistics: unprepared staff; a lack of efficient communication systems; scarce demographic information on the affected area; the difficulty of predicting the unstable demand of beneficiaries; the donation of unnecessary goods; an uncoordinated flow of donations; poor decision-making processes; a lack of cooperation among the main actors involved; and the difficulty of establishing a central coordination of the operation. It is expected that an in-depth assessment, with an analysis of a greater number of humanitarian responses to natural disasters, will allow a more accurate view of these often missed opportunities and organisational solutions, since a greater range of disasters with similar origins would be studied from different sources. The crossing of experiences and best practices will allow the identification of important topics for the exchange and development of shared solutions.

Finally, we can conclude that the development of simple and objective procedures to be applied in field operations is crucial to a more efficient distribution process in disaster response operations that would enable the improvement of the service level.

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