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Invited research paper

On the unique features of post-disaster humanitarian logistics

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ABSTRACT

Logistic activity can be thought of as a socio-technical process whereby a social network of individuals orchestrates a series of technical activities using supporting systems such as transportation and communications. To understand the functioning of the entire system requires proper consideration of all its components. We identify seven key components: the objectives being pursued, the origin of the commodity flows to be transported, knowledge of demand, the decision-making structure, periodicity and volume of logistic activities, and the state of the social networks and supporting systems. Based on our analysis of the differences between commercial and humanitarian logistics, we pinpoint research gaps that need to be filled to enhance both the efficiency of humanitarian logistics and the realism of the mathematical models designed to support it.

We argue that humanitarian logistics is too broad a field to fit neatly into a single definition of operational conditions. At one end of the spectrum we find humanitarian logistic efforts of the kind conducted in long-term disaster recovery and humanitarian assistance, where operational efficiency – akin to commercial logistics – is a prime consideration. At the other, post-disaster humanitarian logistic operations involved in disaster response and short-term recovery activities represent a vastly different operational environment, often in chaotic settings where urgent needs, life-or-death decisions and scarce resources are the norm. The huge contrast between these operational environments requires that they be treated separately.

1. Introduction

Improving the state of the art and practice of humanitarian logistics (HL) has huge economic and social implications as there is ample evidence that the human and economic impacts of natural disasters are increasing (Centre of Research for the Epidemiology of Disasters, 2009). According to the Office of U.S. Foreign Disaster Assistance and the Center for Research on the Epidemiology of Disasters, in 2010 more than 297,000 people were killed and over 217 million were affected by natural disasters, and the economic damage has been estimated at over US$123.9 billion (Guha-Sapir et al., 2011). However, research on HL is simply not commensurate with its crucial role, particularly those aspects concerning characterization. The number of empirical studies of real life HL efforts is pitifully small. Part of the problem is that the HL practitioner community is very small – no more than a few thousand individuals in the entire world could claim HL as their full-time occupation. Given the minuscule size of the community, as well as its reluctance to produce publicly available accounts of actual HL efforts, only those individuals directly involved are familiar with the intricate details of the operations. In our view this represents a major obstacle to the development of relevant analytical models, since it is not possible to develop accurate models of a system that is poorly understood.

In contrast, the functioning, features and dynamics of commercial logistics are well known, hence researchers have been able to develop highly sophisticated analytical models to optimize the various components of modern supply chains. Together with the development of advanced distribution systems, this has dramatically enhanced performance. To give one illustration of this, transportation's share of total production costs fell by 52.3% between 1970 and 2002 (Chopra and Meindl, 2007).

The disparity between commercial and humanitarian logistics has prompted attempts to adapt analytical formulations originally developed for the commercial sector to the humanitarian context.

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While undoubtedly pragmatic, such adaptations have major limitations since commercial and humanitarian logistics are recognized as being radically different (Beamon, 2004; Beamon and Kotleba, 2006; Van Wassenhove, 2006; Holguín-Veras et al., 2007) and most analytical formulations fail to fully capture the complexity of HL.

This paper identifies differences between commercial logistics and the key variants of HL. The term 'humanitarian logistics' encompasses a wide range of operations including the distribution of medical supplies for routine disease prevention, food supplies to fight hunger, and critical supplies in the aftermath of a disaster. While these share humanitarian goals, they are profoundly different on account of the level of urgency of the operations, the state of the social networks that orchestrate the effort, the state of the supporting systems, and the dynamic nature of the needs, among others. Treating HL as a homogeneous block glosses over the complexity and distinctness of the various operational environments, making it difficult for outsiders to understand the unique features of the different types of HL and to develop suitable analytical formulations. While previous comparisons between commercial logistics and HL have been made (Beamon, 2004; Holguín-Veras et al., 2007), the role of social networks and the differences between the various modalities of HL have been largely overlooked. In analyzing the key forms of HL, our main emphasis is on post-disaster operations, where the contrast with commercial logistics is most extreme. For this reason we discuss cases from the literature and from our fieldwork on post-disaster humanitarian logistics (PD-HL).

The remainder of the paper is organized as follows. Section 2 focuses on the analysis of the differences between disasters and catastrophes from the standpoint of their respective impacts on the HL response. Section 3 discusses the differences between commercial and HL based on the disaster research literature, fieldwork by the authors, direct observation of prominent cases (e.g., World Trade Center, Hurricane Katrina, Haiti, Japan), and comprehensive analyses of the HL process. Section 4 presents an outline of research needs aimed at addressing the most pressing knowledge gaps related to PD-HL. We conclude with a summary of our key findings.

2. Disasters vs catastrophes

One of the most important factors impacting HL is the nature of the event itself. In particular, it is important to distinguish between a disaster and a catastrophe. There is no general agreement among researchers on how to define the term "disaster" (see Perry (2006) and Federal Emergency Management Agency (2004) for a comprehensive discussion), and the issues involved are complex, as articulated by Quarantelli (1998, 225): ". . .to be concerned about what is meant by the term disaster is not to engage in some useless or pointless academic exercise. It is instead to focus in a fundamental way on what should be considered important and significant. . ."

The term disaster is used here to refer to ". . .a non-routine event that exceeds the capacity of the affected area to respond to it in such a way as to save lives; to preserve property; and to maintain the social, ecological, economic, and political stability of the affected region. . ." (Pearce, 2000). While this definition is grounded in a conception of a disaster as external to the system, others such as Wisner et al. (2004) hold the view that a disaster is internal to the system itself. The distinction between catastrophic and non-catastrophic disasters is important, but the need to consider how they impact the socio-technical process of PD-HL has only been recognized relatively recently. We build on our previous work by providing a more comprehensive analysis of the impacts on PD-HL (Wachtendorf et al., 2012).

Catastrophes can be defined as high-consequence events that generate widespread and crippling impacts, where the ability of the impacted society to respond is severely compromised. They range in scale from cases where the impacted country can cope, to those where the country has to invite outside assistance, either regional or global. How the country copes will very much depend on the strength of the government and society, and the vulnerability of the population. In Haiti and Somalia, even a relatively minor disaster can have huge consequences, whereas Japan has well-developed disaster-response mechanisms.

Technically, a catastrophic event is one in which "most or all of the community-built structure is heavily impacted. . . [and] facilities and operational bases of most emergency organizations are themselves usually hit"; "local officials are unable to undertake their usual work role"; "help from nearby communities cannot be provided"; "most, if not all, of the everyday community functions are sharply and concurrently interrupted"; "the mass media system especially in recent times socially constructs catastrophes even more than they do disasters"; there are "mass out-migrations for protracted periods of time"; and, "because of the previous six impacts, the political arena becomes even more important" (Quarantelli, 2006; Wachtendorf et al., 2012). A catastrophe does not have to exhibit all seven characteristics, but the prevalence of multiple characteristics is an indication of how catastrophic an event is. The Tohoku (Japan) tsunami's impact on the town of Minani Sanriku, and the Port-au-Prince earthquake (Haiti) exemplify catastrophic events.

A non-catastrophic disaster is one in which the local population, authorities and humanitarian organizations can cope with the consequences despite significant casualties and destruction of infrastructure. The response involves fewer converging entities, less of an interface between the public and private sectors, and allows more autonomy and freedom of action (Quarantelli, 2006). The tornado that devastated a narrow strip of Joplin, Missouri, leaving surrounding areas untouched is an example. In terms of the HL effort, in the event of a catastrophe the majority of supplies have to be brought from (well) outside the impacted area, while in a non-catastrophic scenario some resources remain (e.g., trucks, leadership structures, inventory stocks at households and businesses) that could become the first wave of aid to the needy (Wachtendorf et al., 2012).

Table 1 summarizes the most salient impacts. As shown, there are major qualitative and quantitative differences between the HL efforts required after disasters and after catastrophes. The first concerns the impact of the event on local inventory held by both households and businesses. After a disaster these are likely to survive in significant amounts, particularly outside the directly impacted areas, whereas a catastrophe – by definition – will destroy or damage the vast majority of local supplies. Thus local supplies play a key role in the response to a disaster but almost no role in the response to a catastrophe.

The second difference concerns the demand for critical supplies to satisfy the needs of both the surviving population and the response process, respectively referred to as "disaster agent-generated" and "disaster response-generated" (Dynes et al., 1972). The demand for supplies, though significant in the case of a disaster, is much larger after a catastrophic event. Adding to the problem is the tendency of individuals and businesses to stock up on essential supplies in anticipation of shortages, such as before a hurricane or a snow storm, or after the sudden onset of a disaster, either for personal consumption or when they see an opportunity to profit from shortages. The magnitude of the demand increase may be significant. For example, the head of a major retailer and food distributor located in Tohoku reported that orders from businesses in the areas surrounding the towns destroyed by the tsunami doubled in the days after the March 2011 disaster (Holguín-Veras et al., 2011b). Such behavior strengthens the case for public-sector requisition of supplies

Table 1
Impacts of disasters and catastrophes on supplies and needs.

Characteristic	Disaster	Catastrophe
Local inventories of supplies (businesses, households)	Only partially destroyed, the surviving supplies may become part of the response	Mostly destroyed, the role of local supplies in the response is minimal
Demand for supplies	Increases due to the needs of businesses, people, and the response. Precautionary/opportunistic buying could be a problem	Huge increases due to magnitude of impacts. Precautionary/opportunistic buying could be a problem in nearby areas.
Private sector supply chains	Partially impacted but functional. Could help in response	Severed, destroyed, cannot help in response
Complexity of local distribution effort	Challenging, but manageable	Exceedingly complex, due to size of impacted area, and manpower required
Net result	Local help is key in initial days, outside help brings additional supplies	Outside help is the primary source of supplies

to ensure that available inventory is put to the best use possible.

The impact of the event on private-sector supply chains, which in normal circumstances bring all or most of the supplies to the area, will affect the social networks in charge of the logistics effort, the equipment/facilities used for technical activities, and supporting systems such as transportation. Obviously, the extent of these impacts will depend on the magnitude of the event. In the case of a disaster where only part of the community is severely impacted, private-sector supply chains may continue to function. Those that have been hit may recover relatively quickly and start bringing in supplies. In a catastrophic event, the human, social and physical infrastructure required to perform the logistical functions may have been destroyed or severely compromised, depriving the private sector of the role it ordinarily plays since it can take weeks to recover, as the authors found in both Haiti and Japan. The same applies to the routine emergency distribution system (Wachtendorf et al., 2012).

In the case of Haiti, although a trickle of local products started to appear six days after the earthquake (New York Times, 2010b, 2010a), it took more than 2 weeks for the "...surviving supermarkets..." to reopen (New York Times, 2010c). In the case of the Tohoku region, the impacts were more severe. We know from interviews with one of the largest Japanese food distributors (Holguín-Veras et al., 2011a) working in Tohoku when the tsunami hit that their operations were suspended for ten days. On the tenth day, operations from distribution centers to distribution centers resumed (no local deliveries) and businesses were obliged to get supplies from the distribution centers. Regular deliveries to businesses outside the disaster area resumed 2 weeks after the tsunami. Months after the event, deliveries within the disaster area had not yet resumed. The experiences of Port-au-Prince and Japan show that while it is not realistic to expect the (local) private sector to mobilize in the immediate aftermath, once it gets going it is difficult to close the relief gates or lessen the flow.

There is also a substantial difference in terms of the complexity of the local delivery effort. After a disaster, due to the size of the impacted area and the effects on the population, local distribution may be challenging but still manageable. This is not the case after a catastrophic event for the simple reason that it requires: (1) considerable resources e.g., manpower, (2) distribution efforts spanning a large area, (3) travel over relatively long distances where the transportation infrastructure has been devastated, and (4) logistical operations of great complexity that can involve tens of thousands of individuals who must be organized, trained and deployed across the geography of the disaster area. We estimate that delivering and distributing supplies to the two million Port-au-Prince residents after the 2010 earthquake required 20,000 staff members (comparable in size to a US Army division, which takes 3–4 weeks to fully deploy).

The net result is that in a disaster, the local social networks involved in commercial logistics are typically able to respond, local resources may provide a first wave of aid, local supply chains respond fairly quickly, and local distribution of supplies may be organized relatively rapidly. In contrast, after a catastrophe local social networks are likely to be severely disrupted, available supplies will be minimal, private-sector supply chains may be out of operation for weeks, there will be a huge increase in demand for supplies, and a complex distribution effort will be required to satisfy the needs of both survivors and the responders. In essence, most of the supplies and the underlying logistics must be brought in from outside.

These observations have important policy implications. While it is frequently assumed that local responders will be able to provide the resources needed for the first 24–48 h of the response (U.S. Department of Homeland Security, 2004), our fieldwork and study of catastrophic events suggest that this assumption is much less realistic in the event of a catastrophe than a disaster.

3. Commercial and humanitarian logistics

Commercial logistics are primarily concerned with the optimization of different facets of manufacturing, distribution and waste retrieval. They encompass a wide range of activities which require specific analytical models. Central to the discussion is that: (1) the main objective of commercial logistics is to either minimize the cost of transportation or logistics (i.e., the summation of inventory and transportation costs); (2) the cargo to be transported clearly originates from the company suppliers and flows to the company's customers, and the nature of the cargo is known; (3) not only are the origin and destination of the cargo known, but so is the demand, enabling the company to optimize its actions; (4) there are established decision-making procedures, involving a relatively small set of decision makers; (5) the logistics system transports large volumes of cargo on a routine basis, which enables it to optimize operations; (6) the social networks in charge of logistical operations are intact and functioning at capacity; and (7) all these activities take place in conditions in which the supporting systems, e.g., transportation, are relatively stable and functional.

In contrast, humanitarian logistics cover a wide range of activities that occur at any one of the phases of emergency management, i.e., mitigation, preparedness, response and recovery (National Governors' Association Center for Policy Research, 1979; FEMA IS-1, 2010). Mitigation and preparedness activities are performed before the disaster to enhance safety and reduce the potential impact on people and infrastructure, for example, practice drills related to relief distribution, pre-positioning of critical supplies, and building codes. Response-related HL activities include the transportation of supplies and equipment for search and rescue, and of equipment and material for emergency repairs to the infrastructure (FEMA IS-1, 2010).

The recovery process is characterized by two sub-phases (Natural Hazards Research and Applications Information Center, 2005, Sections 2–4). Short-term recovery is the transitional stage between response and long-term recovery, where activities such as managing donations and volunteers, conducting damage assessments, securing temporary housing, restoring lifelines and clearing debris take place. Long-term recovery – which may continue for years after the disaster – aims to foster either a return to normality or an improved quality of life, e.g., "to build back better." Activities range from psychological counseling to restoration of infrastructure, and may include humanitarian assistance such as the distribution of medical supplies for routine disease prevention, and food supplies to prevent hunger and malnutrition (Natural Hazards Research and Applications Information Center, 2005, Sections 2–4).

Although sharing a humanitarian goal, the logistical operations conducted in these phases are substantially different. Short-term recovery activities occur in chaotic and challenging circumstances in the aftermath of a disaster, whereas in the long-term recovery phase the logistics activities take place in a more stable setting. Another difference is related to the urgency of the shipments, which will reflect the degree of human suffering involved. In the case of disaster response and short-term recovery, the level of urgency is typically much higher than during long-term recovery and humanitarian assistance. As we discuss below, this has profound implications for our analytical models in terms of reflecting the balance between needs (focus on human suffering) and efficiency (focus on the best use of resources).

A number of disaster agent characteristics impact emergency preparedness and response activities (Kreps, 1995; Pearce, 2000; Tierney et al., 2001), such as (1) the speed of onset, which can be sudden like a tsunami, or gradual like a famine; (2) the time between the identification of the disaster agent and the onset of its effects in a particular place (length of forewarning); (3) the severity of social disruption and physical harm (magnitude of impact); (4) the size (boundaries) and nature of the impacted area or social disruption (scope of impact), e.g., debris after an earthquake or flood water after torrential rain; and (5) the length of time from the initial impact/disruption to when its effects cease (temporal duration of impact). Other characteristics can influence the nature and character of the HL response, such as the frequency or temporal regularity of disasters (Tierney et al., 2001), the persistence of the threat (e.g., a natural disaster like a hurricane, or a man-made conflict leading to large numbers of displaced individuals in refugee camps), and whether or not it is of catastrophic proportions.

In general, regularity, forewarning and speed of onset are important factors for both emergency preparedness and response as they determine whether it is possible to forecast the location and timing of the impact. A slow onset such as the floods in Pakistan in 2010 provides a longer warning time, allowing the population to save some possessions and emergency responders to pre-position supplies, equipment and personnel. A sudden onset causes sharp disruption to the infrastructure, the economy and society (e.g., the 2011 earthquake and tsunami in Japan). People barely have time to flee for their lives and all their possessions are destroyed. These scenarios have obviously different impacts on the immediate resource requirements after the disaster.

In terms of the geographic area impacted, disasters can be localized (such as a small tornado) or widespread, like a flood that impacts a large portion of a country, although not all widespread disasters are catastrophic. Obviously, a localized disaster is easier to respond to than a widespread one because (1) travel times and distances in the segments of the transportation network that have been impacted are smaller, hence supplies arrive more quickly; (2) it is easier to inspect the damage to the network so that alternative delivery plans can be made; and, (3) it is easier to identify and quantify the needs for critical supplies as the population is concentrated in a smaller region. In contrast, after a widespread disaster: (1) delivery vehicles have to travel longer distances via a transportation network where numerous links are destroyed or clogged by debris; (2) there is great uncertainty about the state of the network; (3) the need for critical supplies remains unknown as it is almost impossible to find out what is needed in a large area; and (4) the structure of the distribution network is significantly more complex than in localized disasters, and in some cases may require hundreds of points of distribution (POD) and tens of thousands of trained volunteers scattered across a large area.

The persistence of the threat is also an important factor, as demonstrated by the impact of the nuclear crisis on the response by the Fukushima Prefecture (Japan), where the perception of the risk associated with a pervasive nuclear crisis significantly dampened the flow of supplies and volunteers to Fukushima (Holguín-Veras et al., in review-b). In one notable case, 36 trucks loaded with urgently needed fuel were abandoned by drivers at the border of the prefecture – far from the exclusion zone – who refused to run the risk of nuclear contamination (Holguín-Veras et al., in review-b). Even the US Navy temporarily pulled out of the Fukushima area due to the risk of nuclear fallout (Reuters, 2011). Moreover, at the height of the nuclear crisis, the risk of contamination led the Government to order people in the exclusion zone to stay indoors. With private-sector supply chains not functioning and a severely curtailed flow of volunteers and humanitarian relief supplies reaching the area, thousands of residents in the exclusion zone were trapped in their homes without access to life-sustaining items. They could neither flee to safety nor receive the supplies needed. A plea for outside help by the mayor of Minami Soma dramatically illustrated their plight (Sakurai, 2011). This stands in sharp contrast with disasters where, once the original disruption has subsided, the response can start in earnest.

The magnitude of the logistical challenge in terms of the volume of cargo to be transported after a disaster is significant. As a benchmark it is useful to look at how much is transported to cities under normal conditions, both for human consumption and to satisfy the needs of manufacturing and industry. For example, for every resident in New York City (Wood, 1970; Holguín-Veras et al., 2010), 625 kg of water (for all urban uses), 20 kg of fuel for heating, transportation and electricity generation, 3 kg of food (including container weight), and about 12 kg of other raw and semi-manufactured consumer goods are transported every day.

The needs are different in a post-disaster context because many existing activities that consume freight disappear, while others that generate freight demand are created. The volume of cargo per capita depends on the needs to be satisfied, ranging from a bare minimum (subsistence level) to a standard that enables survivors to satisfy other needs. The U.S. Army Corps of Engineers (2010) specifies a minimum per person of a bag of ice (5 kg), a gallon of water (4 kg) and 2 meals-ready-to-eat (MREs) (1 kg) per day, which translates into 5 kg of supplies per day (10 kg if ice is provided). The minimum standard set by the Sphere Project is 7.5–15 kg of water per day (without water for sanitation), and an energy intake of about 2000 Kcal, obtained from half a kilogram of food (e.g., maize, rice, beans) (The Sphere Project, 2011). However, these estimates do not take into account that individuals who have lost their possessions have other basic needs such as clothing, kitchen and cleaning utensils, and medicine. The interviews we conducted indicated that the survivors of the Tohoku disaster received about 20 kg per person/day during the first weeks (Holguín-Veras et al., in review-b). Suffice it to say that anywhere between 5 kg and 20 kg per person/day of supplies will be required.

In addition to supplies for survivors, the HL system must deliver supplies to meet the needs of the response process. These include: (1) food and water for the responders; (2) equipment and supplies for medical teams, search and rescue, security forces; and (3) transportation, construction equipment and fuel. Although there are no publicly available data, we estimate – based on the Katrina experience – that response-generated demand is two to three times the volume of cargo destined for the survivors (Holguín-Veras and Jaller, 2012). This implies that in the days after a major disaster, between 15 kg and 80 kg per person/day will be needed to satisfy the needs of both constituencies. For example, the two million residents of Port-au-Prince required a minimum 30,000 metric tons of supplies (or 1500 loaded semitrailers) per day, to be distributed across more than 90 km^2 of difficult terrain. The magnitude of the challenge in the case of large urban disasters and catastrophes is monumental.

A wide range of conditions will determine the characteristics of a humanitarian operation. We focus on the two ends of the operational spectrum. The first represents the most extreme form, in the initial response and short-term recovery phase, referred to as "post-disaster humanitarian logistics" (PD-HL). The second, regular humanitarian logistics (R-HL), is concerned with operations in which the main purpose is either long-term recovery or humanitarian assistance which, with the exception of the humanitarian goal, are akin to the commercial paradigm. In this instance 'regular' refers to the frequency and relative stability of the setting, although they often take place in challenging circumstances. Between these extremes there is a continuum of conditions but by focusing on them we indicate the breadth of the field.

To understand the differences between commercial and humanitarian logistics requires a holistic view of the entire logistics process. As mentioned in the introduction, central to the holistic study of the effort is the recognition that logistic activity is a socio-technical process that uses a set of supporting systems. A social network of individuals (e.g., carriers, drivers, receivers, warehouse operators) arranges a series of technical tasks (e.g., inventory management, routing, pricing) that depend on the supporting systems available at that particular location (e.g., transportation systems, communication technologies). Logistic activity thus involves three complementary components: a social network, the technical activities it performs, and the underlying support systems they depend on. As a result of the interlinkages between these components, a malfunction in any of them could bring the entire process to a halt. For this reason we must consider all components in holistic fashion, as illustrated by Table 2 which offers a comparison along seven key dimensions.

The remainder of this section discusses these characteristics to highlight commonalities and differences between the cases considered.

3.1. Objectives being pursued: social costs = logistic costs + deprivation costs

The main distinction between commercial and humanitarian logistics is related to their respective objectives. The reason for this has to do with the requirement that the model establish an isomorphic relation with the reality that it seeks to represent (i.e., that it captures the reality). If the model does not do so, albeit with some simplifications, we will be unable to draw sound conclusions. While acknowledging that there are cases where participating agents pursue objectives that do not live up to ideals, such as politicians who use relief aid as an instrument of local politics, and even relief agencies that use aid to promote their social agenda, the discussion here centers on what may be deemed the ideal objectives.

In commercial logistics, agents conducting an economic transaction (e.g., shippers, carriers, receivers) internalize all costs and benefits in the context of a formal market. These are said to be "private" (Varian, 1992), hence their main objective is to minimize the total logistics costs associated with the operations, subject to a set of operational constraints. Conversely, HL is primarily concerned with human suffering (well-being). The suffering brought about by the lack of a good or service – which can be regarded as a "deprivation cost" – is not internalized by participants in the distribution chain. Thus, economically speaking, deprivation costs are "external" or externalities (Varian, 1992). As discussed in the welfare economics literature (Pigou, 1920), if the decision maker does not consider the externalities in the decision process, the most efficient outcome for the system cannot be reached. It is this concept that provides the theoretical support for taxation of externalities such as the "polluter pays" principle.

By extension, if the mathematical models developed to support the decision-making process do not incorporate externalities in an appropriate fashion, they will fail to identify the socially optimal outcomes in terms of delivery strategy. It follows that if we are to identify the optimal delivery strategy we must explicitly incorporate the externalities into the objective functions by using the concept of social costs, i.e., the summation of private and external costs. In the post-disaster case, the event itself is the one that produces human suffering. However, when making decisions about how to distribure the aid, the relief groups generate two externalities. The first one is the positive externality associated with the reduction of the human suffering on the part of the individuals that received the aid. The second externality is negative as it represents the increase in human suffering (deprivation cost) accrued by the individuals that did not receive aid at that particular point in time. This represents the opportunity cost of the delivery strategy. In essence, both externalities must be accounted for. Thus, HL formulations must account for both the private costs (e.g., transportation, inventory and handling) and the changes in deprivation costs produced by the delivery strategy. This issue has been intuitively understood by researchers who incorporate proxies for deprivation costs (e.g., delivery penalties, equity constraints, minimum delivery frequency). A key limitation of these approaches, as discussed elsewhere (Holguín-Veras et al., in review-a), is that the use of proxy measures of deprivation costs in PD-HL models may yield solutions that are radically different from those obtained if deprivation costs are appropriately considered. In other words, such measures may not work well for PD-HL.

The core issue is the relative importance of deprivation costs vis-a-vis logistics (transportation plus inventory) costs. In cases where deprivation costs are relatively minor, the use of models inspired by commercial logistics is bound to work well, whereas in conditions of extreme deprivation where logistic costs are hardly a consideration, models based on the commercial logistic paradigm may not work because they cannot capture the full complexity of the deprivation costs (e.g., non-additive demands, non-linearity, hysteresis) (Holguín-Veras et al., in review-a). To understand such complex elements we turn to the medical literature on starvation (Keys et al., 1950) and the literature of hysteretic economic systems (Cross, 1993). Deprivation costs are associated with non-additive demands because after a period of deprivation, total demand is not equal to the individual demand in the different time periods, e.g., a person that has not eaten for five days cannot eat five days worth of food even if given the opportunity. Hence the deprivation costs are non-linear because of the way in which the human body deals with privation. At the initial stage of the deprivation cycle, lack of a life-sustaining item does not have a major impact on an initially healthy person. But at some point body functions will slow down, suffering will increase, and thus a non-linear deprivation cost function is appropriate. Deprivation costs may be hysteretic if an individual exposed to a deprivation cycle does not fully recover from the experience during the fulfillment cycle; non-hysteretic if they do. None of these complex features are taken into account by existing analytical models. Indeed, finding appropriate proxies for something as complex as deprivation costs may not be possible since,

Table 2
Differences between commercial and humanitarian logistics.

Characteristic	Commercial logistics	Regular humanitarian logistics (R-HL)	Post-disaster humanitarian logistics (PD-HL)
Objective pursued	Minimization of private (logistic) costs	Minimization of social costs (logistic + deprivation)	Minimization of social costs (deprivation + logistic)
Origination of the commodity flows	Self-contained	Self-contained	Impacted by material convergence
Knowledge of demand	Known with some certainty	Known with some certainty	Unknown/dynamic, lack of information/access to site
Decision making structure	Structured interactions controlled by few DMs	Structured interactions controlled by few DMs	Non-structured interactions, thousands of DMs
Periodicity/volume of logistic activities	Repetitive, relative steady flows, “large” volumes	Repetitive, relative steady flows, “large” volumes	Once in a lifetime, large unexpected pulse, “small” volumes
State of social fabric and networks	Normal, as usual	Under stress though stable	Severely impacted, in flux
Supporting systems (e.g., transportation)	Stable and functional	Compromised but nearly stable and functional	Impacted and dynamically changing

Notes: “DMs” refers to decision makers. “Deprivation cost” refers to the human suffering brought about by the lack of a good or service. “Material convergence” refers to large quantities of goods arriving at the disaster site.

when they are extreme, proxy measures cannot properly account for them. Thus, proxy-based models can be expected to work reasonably well in R-HL, but significantly less so for PD-HL decision making.

In essence, the commercial logistic paradigm can be regarded as a particular case of a more general model where deprivation costs are negligible. Disasters typically have a lifecycle whereby the balance between deprivation costs and the need to be efficient evolves. In the immediate aftermath of a major disaster the emphasis will be on reducing human suffering; a few weeks later the situation may be sufficiently under control to focus more on “doing more with less,” i.e., serving more people with limited funds.

3.2. Origins of the commodity flows: material convergence

An important and frequently overlooked difference between commercial and humanitarian logistics has to do with how the commodity flows reaching the impacted site are generated. In the case of commercial logistics, the delivery actions of a company reflect the commodity flows from producers/shippers to receivers/users, as well as the competitive nature of the market. Thus the commodity flows generated are within the control of the companies involved. A similar situation can be expected in R-HL where the origin and destination of supplies are relatively fixed and flows are regular, though donors may earmark funding for specific purposes and even impose suppliers. Thus, even in R-HL there may be substantial differences with commercial logistics because of these donor constraints.

However, in PD-HL, and particularly in the aftermath of a major disaster, the situation could not be more different. In response to a large-scale disaster, tens or even hundreds of thousands of donors (be they governments, communities or individuals) send massive amounts of supplies and equipment. In some cases these originate from inventory stocks held by organizations; more often than not they come from donation drives organized by local communities. We refer to this phenomenon as material convergence, consistent with the disaster literature (Fritz and Mathewson, 1957). The problem of material convergence is that although it brings in much-needed supplies, a significant portion of useless unsolicited donations creates major complications for the disaster response. While it may seem counterintuitive that the donations of well-meaning individuals could have such consequences, the evidence is overwhelming. Recent experiences in Port-au-Prince (Haiti) and Tohoku (Japan) (Holguín-Veras and Jaller, 2010a,b,c,d; Holguín-Veras et al., in review-b; Jaller, 2011) show that the issue is as pertinent as it was 60 years ago (Fritz and Mathewson, 1957).

While material convergence brings much needed supplies, attention has focused on the negative impacts of not-needed goods. For example, Fritz and Mathewson (1957) conclude that the flow may substantially impede organized relief efforts because: (1) the volume far exceeds actual needs; (2) it is mainly comprised of unneeded, unusable materials; (3) it utilizes personnel and facilities which could be used for more essential tasks; (4) it often causes conflict among relief agencies or segments of the population; (5) it adds to the problem of congestion in and near the disaster site; and (6) may disrupt the local economy. The American Red Cross considers that “Unsolicited, spontaneous donations of goods and services from individuals and community groups, though well intentioned, have hidden costs and pose a number of complications for relief efforts.” (American Red Cross, 2011). Nevertheless, humanitarian organizations remain reluctant to refuse shipments for fear of upsetting donors which might negatively impact future funding.

While such flows are typically dubbed “unsolicited donations,” “volunteered donations,” and “unofficial donations”, they can actually include high-priority items donated by governments and international relief agencies that frequently dispatch critical supplies to disaster zones without being formally asked. For this reason we prefer the classification developed by the PAHO as it focuses on the usefulness of the items rather than their origin. The PAHO classification was defined as part of its Humanitarian Supply Management System (SUMA) which, tellingly, was developed to help resolve problems involved in the mass arrival of assistance in a region affected by a disaster. The classification considers three classes of goods: *urgent* or *high priority* (*HP*), *non-urgent* or *low priority* (*LP*) and *non-priority* (*NP*) (Pan American Health Organization, 2001, 70). Urgent or high-priority goods are those items which are required for immediate distribution and consumption. Non-urgent or low-priority goods are not immediately required, but might prove useful at a later stage, and thus must be classified, labeled and stored until needed. Non-priority goods are those that: (1) are inappropriate for the event, time, context, population; (2) arrive unsorted or in a condition impossible to efficiently inventory/identify; (3) have surpassed expiry dates, are perishable, or are in poor condition; (4) arrive without a known or appropriate site for efficient distribution; and (5) are useless or of doubtful value. In most cases they must be discarded to make room for useful supplies. Depending on their nature, they may be incinerated, buried, or otherwise disposed of (Pan American Health Organization, 2001, 70).

Experience has clearly shown that the flow of non-priority items is by far the most problematic. Indeed it is so serious that disaster responders have called it “a second tier disaster” (Newsweek, 2002). Not surprisingly, when the authors asked professional logisticians involved in PD-HL after the Haiti earthquake what they considered to be the most significant obstacle to the response, the consensus was "unsolicited donations" (Holguín-Veras and Jaller, 2010a,b,c,d; Jaller, 2011). The same was observed in Japan after the Tohoku disasters (Holguín-Veras et al., in review-b).

However, non-priority goods are not the only problem; low-priority supplies can be equally vexing if they arrive in large numbers, as the Tohoku disaster illustrates (Holguín-Veras et al., in review-b). In response to news reports that the earthquake victims needed blankets due to cold weather, donors rushed to send blankets to Tohoku (including numerous Japanese prefectures that had large stores of blankets for disaster response purposes). As a result, the volume was much larger than the actual needs. While a tiny fraction of these blankets were needed during the first week of the crisis because of the cold, once the weather warmed up they became a nuisance as they continued to arrive from far-away countries. By March 23rd 2011, more than 110,000 blankets had arrived from overseas (Japan Times, 2011; Kyodo News, 2011a). Not surprisingly, when asked about non-priority goods, most of the individuals interviewed mentioned "too many blankets" (and clothing) as the most problematic items. The same could be said of bottled water, and face masks (Holguín-Veras et al., in review-b).

The problem of material convergence has been identified in all major disasters (Fritz and Mathewson, 1957; Boileau et al., 1978; Wettenhall, 1979; Scanlon, 1991; Neal, 1994; Holguín-Veras et al., 2007). Regrettably though, there have been very few attempts to analyze its effects on logistics and material convergence has not been explicitly considered in analytical models for PD-HL. As a result there is no established procedure for simultaneously handling the material convergence problem and expediting the flow of high-priority supplies.

3.3. The decision-making structure

There is a vast difference between the decision-making process involved in commercial logistics and the variants of HL. Commercial logistics are managed by a small number of decision makers using formal decision-making structures, standard procedures and with clearly defined roles and responsibilities for all players. Each participant knows what they are supposed to do and how to interact with others. Established protocols enforce compliance with rules and regulations. In short, it is a mature and highly structured market, with common information systems, standardization, transparency and visibility, accountability, clear objectives and well aligned incentives.

While R-HL may be relatively close to commercial logistics in terms of activities and flows, the process emerges in response to a crisis. There may be little standardization, limited transparency (tracking and tracing is unusual), high fragmentation, poor coordination, strongly decentralized decision making, and misaligned incentives. Furthermore, the beneficiaries do not have the power that customers typically wield in a commercial setting, let alone the opportunity to choose between a multitude of product offers.

In contrast, PD-HL are highly dynamic, often informal and/or improvized, and far from unified – thousands of independent supply chains may overlap, compete, interfere, cooperate, and even battle for the scarce resources available. This is a direct consequence of material convergence, which generates countless supply chains that transport miscellaneous goods to the disaster area. Some are tiny, e.g., a truck transporting donations from a church; others are vast, e.g., the United Nations Logistic Cluster. Research conducted on material convergence after Katrina found in excess of 1000 donation drives that sent goods to New Orleans (each of them being a supply chain) (Destro and Holguín-Veras, 2011). This probably underestimated the actual number as it included only those covered by the media. Indeed, it would not surprise us if there were tens of thousands of such supply chains, each trying to deliver donations to New Orleans.

"Coordinating" efforts among these minuscule supply chains may be impossible because there is no information about who they are, what supplies they are bringing, or their intended destination and time of arrival. Orchestrating the efforts of responders with different professional backgrounds, levels of expertize and priorities, all operating under different organizational structures, is a huge challenge, as illustrated by the valiant efforts of groups like the Volunteer Organizations Active in Disasters (VOAD), or United Nations' Office for Coordination of Humanitarian Affairs (OCHA). Moreover, their task becomes paramount if the government is unable to coordinate the relief effort, as in Haiti. Conversely, VIP and media visits consume scarce resources (e.g. helicopter time), even if they do play a key role in generating public support.

3.4. Knowledge of demand

Commercial logistics are designed to meet known or forecast customer demands for the portfolio of goods offered by the company. While there may be variations in demand patterns, the level of uncertainty is relatively small compared to the base demand, whereas in the aftermath of a disaster there is huge uncertainty about what and how much is needed and who needs what – particularly where there has been a major impact on transportation and communication systems. A complicating factor is that a disaster may require order-of-magnitude increases in the volume of critical supplies to be transported.

R-HL is somewhere in between the commercial and the PD-HL case as the needs may be reasonably well established – less accurately than in the commercial case, but more so than in post-disaster conditions. A typical example of R-HL would be the transport of relief items to a crisis region. While needs may be relatively known and stable, transport corridors may be uncertain (or even broken) due to rapidly changing security conditions. Roads and bridges may require repair to allow for land transportation instead of expensive air transportation. In short, the supply chain context is very different from most commercial logistics environments. In the case of conflicts, it is difficult to predict the outcome or to forecast migration due to people leaving camps to return home. Obviously, such migrations heavily affect the demand for and the origins/destinations of flows of relief items.

As indicated, the supplies to be transported must satisfy the needs of the population ("agent-generated demands") and the response process itself ("response-generated demands") (Dynes et al., 1972). An analysis of the resource requirements after Hurricane Katrina made by the State of Louisiana to the Federal Emergency Management Agency (FEMA) revealed that the majority of requests (74%) were disaster response-generated (e.g., transportation equipment, electrical equipment, machinery, plastic and rubber, chemical manufacturing, telecommunications, personnel, petroleum and coal products, metal manufacturing), while only 26% were disaster agent-generated (e.g., water and ice, medical supplies, food, clothing, and paper products) (Holguín-Veras and Jaller, 2012). The large proportion of response-generated requests reflected FEMA's involvement in all phases of disaster response activities (e.g., search and rescue, safety) and the fact that survivors' needs may have been satisfied by other organizations (e.g., the Red Cross, private sector, volunteers). Taking into account the supplies brought by these groups – primarily to the benefit of survivors – it seems reasonable to assume that response-generated demands represented two to three times the amount of agent-generated demands. The temporal pattern of requests is shown in Fig. 1, after Holguín-Veras and Jaller (2012).

As shown, the total number of requests dramatically increases in the first six days of the event and then tapers off. Such an increase across all types of supplies has few parallels in commercial logistics, particularly taking into account that each request is for a large

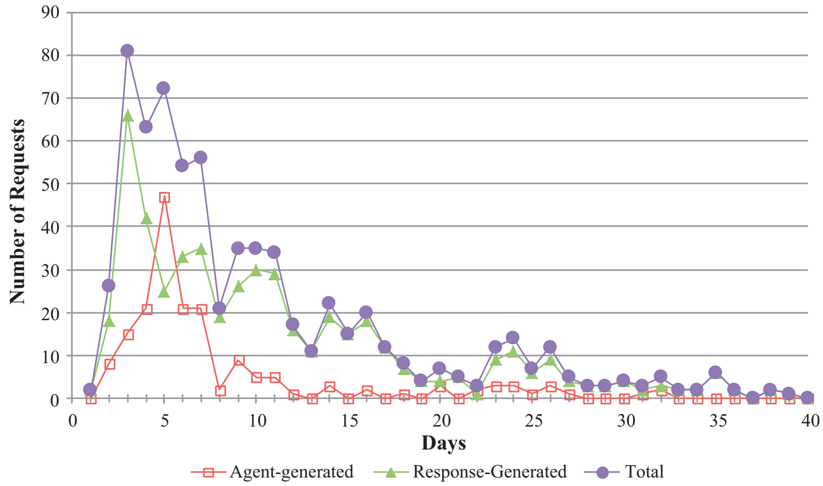

Fig. 1. Number of requests for critical supplies after Hurricane Katrina.

volume of commodities. The closest commercial supply chains come to this type of situation would be for the launch of a new product with a short lifecycle, e.g. an extremely popular new product. In the early days of the crisis, the bulk of the requests are related to the response itself (justifiably so, since without these supplies the response cannot take place). After a peak on day three, the number of response-generated requests declines. In contrast, the agent generated requests – that exhibit a lag with respect to the response-generated ones – peak on day five, after which the number steadily declines.

Adding complexity to the problem, anecdotal evidence suggests the existence of a bullwhip effect (Forrester, 1961; Lee et al., 1997). During the response to Hurricane Katrina, for example, a lack of interoperability between the computer systems used by the Federal Emergency Management Agency (FEMA) and the State of Louisiana (Holguín-Veras et al., 2007) led to a situation in which the individuals requesting critical supplies could not check the status of their orders. Conversely, the FEMA staff processing the orders could not contact the requester to check the validity of the request. The interviews conducted suggested that as a result responders may have repeated the orders in the hope that a second, or a third request would expedite the deliveries. In essence, nobody had a clear idea of what goods were needed, how much, or who needed them. The bullwhip effect is more controlled in commercial supply chains thanks to the transparency and supply chain coordination between partners and facilitated by shared information on enterprise resource planning systems – a stage that the humanitarian world is far from reaching.

The significant increase in the number of requests (and the volume of critical supplies requested) underlines the potential benefits of integrating forecasting and ordering procedures. Forecasting the immediate resource requirements – long recognized as a research priority by FEMA (Picciano, 2002) – would enable the ordering of goods to meet the anticipated needs, thus mitigating the impact of long lead times. This is also linked to decentralization and pre-positioning of critical supplies in regional warehouses which would also avoid long lead times. Even a poor forecast is likely to perform better than a reactive ordering policy. In this context, recent research conducted by the authors clearly demonstrated the feasibility of estimating time-series models to predict the dynamic patterns of resource requests after a disaster (Holguín-Veras and Jaller, 2012). This is an encouraging result because it opens the door to the integration of forecasts of needs into ordering policies and proper pre-positioning as part of look-ahead strategies.

3.5. State of the social fabric and networks

At the core of the logistic activities is a social network of all the individuals involved in logistics. While often overlooked in normal conditions (as their work goes on in the background), it is these social networks that orchestrate the entire effort and make possible the identification of needs, coordination of activities, operating the equipment, routing of vehicles, transportation, warehouse operations, recruiting and training of staff, and so forth. These highly specialized activities rely upon supporting systems that provide the technologies and systems that hold the network together. Under normal circumstances, they work with minimal problems, but when an external shock severely disrupts the social networks that manage logistics, members may be killed or injured, have to focus on helping family or friends, participate in the response process – or have multiple other reasons for not performing their duties.

Moreover, a sudden failure of the supporting systems – particularly transportation and communications – could remove the logical and informational links among the members. In essence, the network – comprised of numerous nodes and active links connecting members – disintegrates into a series of isolated sub-networks or nodes with much less connectivity than the original one. As a result, its ability to re-start the activities associated with the transportation and delivery of supplies may be severely compromised. Thus the humanitarian effort has to either re-create or replace the network, or simply wait for it to be regenerated in order to deliver critical supplies. While there is increasing recognition of the importance of social networks to disaster response (Carley, 1999; Kapucu, 2001; Comfort et al., 2010), their role in the PD-HL process requires further discussion and analysis.

Fig. 2 shows the social connections between a supplier (triangle), its warehouse and trucking venue (rhomboid), and its customers (small circles). In normal conditions (Pane a), the social network is highly connected – both customers and supplier/warehouse can get in touch to coordinate delivery of supplies. Pane b shows the post-disaster conditions where nodes have been destroyed by the event (denoted by crosses), and only a small subset of the original network is still operational. Over time, however, as social links are reestablished, the network can undergo a process of regeneration and adaptation to the new conditions, although some networks simply disappear altogether.

The more resilient the impacted community, the more effective the PD-HL will be as the humanitarian effort can tap into the resources of the existing social networks involved in logistics. Thus

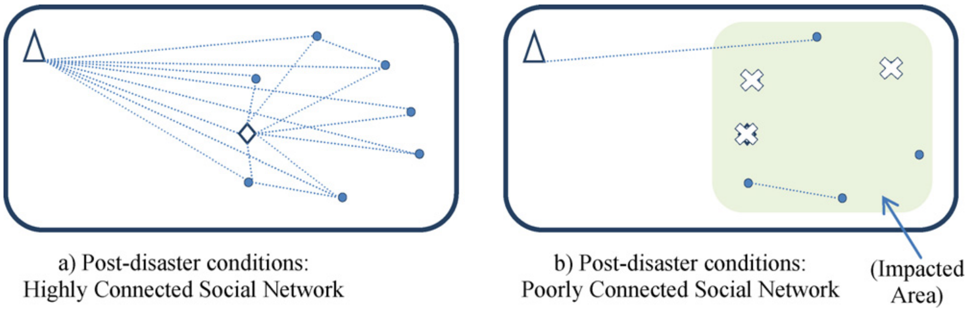

Fig. 2. Schematic of a social network before and after a disaster.

the more resilient the community, the faster the regeneration of the private sector logistic systems and the return to normalcy.

3.6. State of supporting systems

In the context of commercial logistics, decision makers are usually able to optimize the distribution of their products since they can estimate demand with reasonable accuracy and the supporting systems are relatively stable. In contrast, delivering supplies after a disaster is extremely difficult due to the damage to the physical and virtual infrastructure, and the limited (or non-existent) transportation capacity in the affected areas (Holguín-Veras et al., 2007). The earthquakes in Port-au-Prince, and Tohoku provide contrasting examples. In Port-au-Prince, the earthquake severely damaged the port, destroying the piers and the two cranes used to unload ships. It only became operational weeks after the earthquake when a floating pier, brought from the United States, was anchored at the port (United States Southern Command, 2010). The airport suffered considerable damage, particularly to the communication tower and the terminal building, though the runway survived. The arrival of portable air traffic control equipment enabled operations to resume, although this took time as well as prioritization by the US military (United States Southern Command, 2010).

After the Tohoku disaster in Japan, the Sendai Airport was flooded by the tsunami but did not suffer irreparable damage. It was open to emergency traffic eight days after the earthquake (Washington Post, 2011), and partially operational for domestic flights one month later (April 13th, 2011) (Kyodo News, 2011b). The port of Sendai did suffer some damage, as hundreds of containers swept up by the tsunami required a significant clean-up. However, the piers survived, allowing the port to open to relief traffic a week after the event, to fuel tankers eleven days later (Journal of Commerce, 2011c); to domestic container traffic almost three months later (Journal of Commerce, 2011a), and to international traffic six months after the tsunami (Journal of Commerce, 2011b).

The internal capacity of the impacted area to recover from the disaster and restore basic infrastructure, particularly the transportation network, is vital. Here again, the cases of Haiti and Japan offer contrasting examples. Months after the Port-au-Prince earthquake, debris was still blocking streets and arterials. In Japan, 15 out of the 16 East-West routes connecting the Tohoku motorway to the East Coast of Japan, and 97% of the National Route 45 – which had been impacted by the tsunami – had been cleaned up a week after the disaster (MLIT, 2011). This underlines the importance of preparedness and response, well-trained responders, and a resilient population.

In the aftermath of a disaster, distribution plans can only be developed after assessing the state of the transportation network via frequent updates (as new information becomes available). Obviously, the scale of the disaster plays a major role: a hugely flooded area is very different from an area impacted by a tsunami in terms of accessibility and required assets. Delivering supplies to a narrow strip of land impacted by a tsunami – typically from neighboring areas that have not been affected – is comparatively easier than when half a country is flooded, as in Pakistan in 2010. Huge differences also exist between urban and rural disasters: rural areas are more self-supporting and typically have strong social networks.

In this context, satellite imaging and other forms of remote sensing combined with state-of-the-art geographic information systems play a key role in providing responders with an idea of the state of the transportation infrastructure over a wide area. The development of such systems could play a transformative role in PD-HL. Indeed, disaster responders interviewed after the Tohoku disasters lamented that the satellite pictures from Google Earth were not available sooner, as this would have helped them tremendously (Holguín-Veras et al., 2011c; Taniguchi et al., 2011). From the modeling point of view, uncertainty about the state of the supporting systems suggests that the main emphasis should be placed on dynamic routing and scheduling combined with real-time location-tracking of the vehicles making the deliveries. Static routing formulations should be seen as nothing more than an intermediate step toward the development of dynamic models capable of incorporating real-time information about network conditions, vehicle locations and population needs. In a typical R-HL operation, the transportation networks are deficient or not fully functional, even if stable. The relatively stability allows relief groups to plan around infrastructure and logistical deficiencies without the unpredictability of dynamically changing conditions.

3.7. Periodicity and volume of the logistic activity

Another distinction is related to the frequency and volume of logistic activities. In the commercial sector, most delivery activities repeat an established pattern day after day, though there may be variations. This allows companies to gradually optimize their operations. In this respect, commercial and R-HL are relatively similar. In contrast, most PD-HL deals with once-in-a-lifetime events, so the element of learning and improvement by repetition does not occur.

The retailer Wal-Mart, for instance, imported 696,000 twenty-foot equivalent units in 2010 (Brundage, 2011). In contrast, even in a large-scale disaster the amount of cargo is much smaller. In the case of Katrina, from August 28th through October 31st 2005, a total of 864 requests for critical supplies were issued by emergency responders (Holguín-Veras and Jaller, 2012). However, a key difference is that, as shown in Fig. 1, there was a spike in the number of requests in the first days after the disaster which then tapered off. So, while commercial logistics handle a large and relatively steady flow of goods, PD-HL deal with a surge in demand that then subsides. The challenge in PD-HL is that this surge takes place at the point when the social networks and the supporting systems are at their weakest, and when large volumes of low-priority unsolicited donations start to arrive, thus putting the scarce assets available under stress. It is precisely during this ramp-up stage that the military and private companies can provide badly needed assets like trucks, but this requires careful planning, coordination and the establishment of procedures before the disaster strikes.

The picture to emerge from this discussion is that commercial logistics and HL are part of an operational continuum, with commercial logistics at one end, PD-HL at the other, and R-HL somewhere in the middle. At the commercial end, the consideration of deprivation costs is not relevant, while at the PD-HL end it is of paramount importance. The same could be said of the other related characteristics listed in Table 2, such as emergent behavior and material convergence which, though important in the PD-HL, are of no relevance in the commercial logistics case. In between, the various operational conditions found in HL can be thought of as different gradations of the extremes.

4. Research needs

This section discusses the most important research needs regarding PD-HL, the area where additional research could have the largest impact. The analyses made so far highlight the need for a proactive and comprehensive research program to fill the gaps in our knowledge of various facets of PD-HL operations spanning multiple disciplines.

4.1. Research area #1: definition of suitable objective functions

As discussed, commercial and humanitarian logistics pursue fundamentally different objectives. The latter are primarily concerned with the well-being of individuals impacted by a disaster. Again, deciding which metric to use in HL mathematical models is far from straightforward as they must take account of multiple philosophical and economic considerations, adding great complexity to the task.

In our view, the most appropriate approach is to use the concept of social costs, i.e., the summation of the logistic and deprivation costs. This requires a formal definition of the concept of deprivation costs, a metric that attempts to capture the loss of well-being resulting from the lack of a good or service. The use of a deprivation cost metric has numerous advantages. It: (1) considers the complex non-linear and hysteretic impacts of deprivation, originally studied by the Minnesota Semi-Starvation Experiment (Keys et al., 1950), (2) captures the non-additive nature of demand, and (3) overcomes the limitations of the alternative procedures that have been used as proxies of deprivation costs (e.g., delivery penalties, equity constraints). However, in so doing it also leads to numerous computational challenges as well as the issue of how to estimate suitable deprivation cost functions, which necessitates the use of economic valuation techniques (Weisbrod et al., 2009). In this domain the most pressing research gaps are related to:

(1) Theoretical properties that the deprivation cost functions should have to correctly represent the impacts of deprivation of goods and services.
(2) Functional forms that accommodate the expected properties of deprivation costs.
(3) Valuation techniques that produce empirical estimates of deprivation cost functions.
(4) Ethical guidelines for estimating deprivation cost functions and their incorporation in decision support tools.

4.2. Research area #2: material convergence

In spite of its undeniable impact on the overall HL process, the study of material convergence has been largely neglected. There is an urgent need for the systematic study and characterization of the various dynamics concerning the origins/nature of the convergent material flows after a major disaster, specifically:

(1) Determinants of donor behavior and its influence on material convergence.
(2) Quantification of material convergence and its components (high-, low-, non-priority) in real life cases, as well as their temporal evolution.
(3) Role of the media in influencing material convergence.
(4) Impact of non- and low-priority flows in real life cases.
(5) Dynamic control models to allocate resources to manage and physically control material convergence.
(6) Use of quasi real-time gathering of information about emerging donation drives to both quantify donation flows and modify donation behavior.

4.3. Research area #3: decision-making structure

The behavior that arises after disasters translates into decision-making structures that are profoundly different from commercial logistics. Remarkably, some of these emergent HL structures were found to implement extremely efficient operations that out-performed more established organizations, as witnessed in the days after the Haiti earthquake (Holguín-Veras et al., 2012). In spite of this, their role and their inherent characteristics are not accounted for in the humanitarian logistics modeling literature. As a result there is a need to conduct research that focuses on:

(1) Characterization of the HL structures that arise after major disasters.
(2) Study of the interactions between emergent and established HL structures, and the decision process that follows (emerging coordination).
(3) Optimal coordination of the different HL structures.
(4) Impacts of such emergent behavior on HL.
(5) Use of social media to improve coordination.

4.4. Research area #4: knowledge of demand and supply

The lack of knowledge about the immediate resource requirements (demand) and their temporal evolution, and the availability of the critical supplies on site/in transit/expected to arrive in the near future is one of the most vexing problems in HL. Thus there is an urgent need for research that addresses the:

(1) Estimation of immediate resource requirements for both agent- and response-generated demands in the aftermath of a disaster, possibly in combination with the use of remote sensing technology.
(2) Short-term forecasting of immediate resource requirements to support ordering policies.
(3) Use of remote sensing technologies, possibly combined with local sensoring (e.g., GPS enabled cell phones) to assess the state of transportation networks, and identify locations of people in need.

4.5. Research area #5: decision support tools

As a result of the unique and complex features of HL – which are significantly different from the commercial setting – there is an urgent need for analytical tools that capture such complexity and enable disaster responders to determine the best course of action. Topics where analytical developments could be beneficial include:

(1) Routing models that incorporate deprivation costs.
(2) Inventory allocation models that incorporate deprivation costs.
(3) Reverse logistics.
(4) Supply pre-positioning.
(5) Planning of points of distribution.
(6) Optimal (dynamic) allocation of resources to manage material convergence.

4.6. Research area #6: social aspects

There is a need to study ways to increase the resilience of the social networks (both established and emergent) involved in disaster response to ensure their effective participation. This could be part of a broader strategy of building community resiliency and of fostering the involvement of the various segments of the civil society. Aspects of interest include research aimed at:

(1) Effective incorporation of local social networks as an integral part of the response process.
(2) Enhancing resilience of both communities and the social networks engaged in logistics.
(3) Development of a response framework that allows seamless integration between the private sector, the community, and existing community structures.

4.7. Research area #7: public sector policy

The systematic study of the real life complexity of HL will enable the identification of positive behaviors to be fostered and negative behaviors to be discouraged by public-sector policy. Such policies and programs should encompass all phases of disaster mitigation, preparation and response processes with the goal of increasing community resilience, robustness of HL procedures, and the efficiency of the overall response. Specific topics to study include:

(1) The role of incentives and penalties in inducing a more efficient response (e.g., reverse logistics).
(2) The role of public–private sector partnerships.
(3) Coordination mechanisms among emergent and established HL structures.
(4) Media engagement (e.g., to reduce non-priority donations, to mitigate "precautionary/opportunistic buying".
(5) Defining the conditions under which requisition of supplies in the locality should be exercised.

The authors are convinced that a proactive research program that addresses the research questions identified in this section could have a significant impact in enhancing disaster response. Equally significant is that the multidisciplinary nature of these endeavors would spur the development of ideas and concepts not contemplated here.

5. Conclusion

This paper compares and contrasts commercial and humanitarian logistics in order to determine the most salient differences and commonalities. In doing so, it makes the point that the field of humanitarian logistics is too broad to be neatly characterized by a single definition of operational conditions. At one end of the spectrum one finds regular humanitarian logistic efforts (R-HL) of the kind conducted in long-term disaster recovery and humanitarian assistance where operational efficiency – akin to the commercial logistics setting – is a primary consideration. At the other end, post-disaster humanitarian logistic (PD-HL) operations – part of disaster response and short-term recovery activities – take place in chaotic situations where urgent needs, life-or-death decisions, and scarce resources are the norm. The vast differences in these operational environments require that we treat them separately.

We distinguish between disasters and catastrophes. Following a disaster the social networks which orchestrate the technical activities in logistics may remain largely functional, significant amounts of local supplies held by households and businesses may survive, private sector supply chains may remain largely operational (though impacted), hence local responders and the private sector can provide a first wave of resources and a more permanent source of supplies once the private sector recovers. After a catastrophe it can be anticipated that local social networks that manage logistics will be severely disrupted or destroyed, local supplies will be destroyed, private sector supply chains severely disrupted (taking them weeks to fully recover), and the demand for supplies will increase dramatically. In essence, after a catastrophe, most of the supplies have to come from the outside. Complicating the matter, "precautionary/opportunistic buying" by individuals and businesses, both before and after the disaster, contribute to the depletion of inventory. Rather than assuming that local responders will provide a first wave of resources during the first 24–48 h of the response, it should be acknowledged that the bulk of the help, including during the first hours of the response, must come from the outside, not from the local private sector.

We argue that logistics is a socio-technical process that uses a number of supporting systems: a social network of individuals involved in the effort manages, orchestrates, and conducts technical activities, relying on supporting systems such as transportation. Hence problems in any of these components will impact the performance of the entire process. This insight has impelled us to define seven dimensions along which to describe and compare logistical operations: the objectives pursued, origin of the commodity flows, knowledge of demand, decision making structure, periodicity and volume of logistic activities, state of the social networks, and state of supporting systems. We argue that there is a need for significant advances in humanitarian logistics modeling to ensure that analytical formulations adequately take into account the full complexity of the operations. This need is most acute in PD-HL. Here, relief organizations strive to alleviate human suffering at the impacted site, operating in an environment characterized by: an impacted social system and networks; a massive influx of goods due to material convergence; dynamic, fragmented and at times competing supply chains; severe damage to the physical and virtual infrastructure; and short timeframes to respond and prevent loss of lives and property. The situation is aggravated by uncertainty about demand and supply.

The paper identifies seven areas – the definition of suitable objective functions, material convergence, the decision-making structure, knowledge of demand and supply, decision support tools, social aspects, and public sector policy – where additional research should be conducted to improve both basic knowledge of the underpinnings of PD-HL, the level of realism of the analytical models and decision support tools, and the overall efficiency of the HL response. In the opinion of the authors, the various stakeholders in the disaster response community should proactively support such research as they have complementary views of this complex subject.

One of the key insights reported here is that humanitarian logistics encompass a wide range of operational conditions that span different forms of humanitarian assistance – from those set in a stable environment for relatively long periods of time (referred to here as regular humanitarian logistics) to the chaotic, dynamic and ephemeral post-disaster environment (PD-HL). While regular humanitarian logistics operations are relatively similar to the commercial case (although the supply chain context may be very different, as well as the objective function and the constraints imposed by the donors), in PD-HL the situation is very different. We need to develop analytical models that capture the complexity of such operations as current models simply do not take into account the key aspects of PD-HL, and thus risk producing sub-optimal results. This paper calls for a concerted effort to develop a new paradigm of PD-HL models. This is best thought of as a long-term goal since despite commendable work by the research community, the underlying dynamics of PD-HL are still poorly understood and more field and case research is necessary.

Acknowledgments

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