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Strategic planning for disaster relief logistics: lessons from supply chain management

Nezih Altay, *DePaul University*
Sameer Prasad
Jayavel Sounderpandian

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Nezih Altay*

Department of Management,
College of Commerce,
DePaul University,
1 E. Jackson Blvd, Ste 7000, Chicago, IL 60604, USA
Fax: 312-362-6973 E-mail: naltay@depaul.edu
*Corresponding author

Sameer Prasad

University of Wisconsin-Whitewater,
5053 Carlson Hall,
Whitewater, WI 53190, USA
E-mail: prasads@uww.edu

Jayavel Sounderpandian

University of Wisconsin-Parkside,
900 Wood Road,
Kenosha, WI 53144, USA

Abstract: Management of disaster relief logistics requires different techniques at different levels. We identify four stages:

1 strategic planning which concerns high level decisions such as supplier selection and confirmation of communication protocols
2 preparedness which concerns decisions regarding the amount and location of relief supplies to be stored
3 pre-event response which concerns decisions during those occasions when an approaching disaster, such as a hurricane, has been detected
4 post-event response which concerns what needs to be done immediately after a disaster has occurred.

In this article, we concentrate on the strategic planning stage and build an integrated logistics model based on elements of supply chain management theory. This model provides specific recommendations to practitioners and identifies important areas to be researched. We also point out the applicable techniques at each of the other stages and cite relevant literature.

Keywords: strategic planning; disaster relief; logistics; supply chain management; services.

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Biographical notes: Nezih Altay is an Associate Professor of Operations Management in the College of Commerce at DePaul University. His research interests include supply chain security and disruption management as well as management of disaster response and recovery operations. Specifically, he is interested in the use of analytical approaches in this context and disseminates his findings in respectable journals such as the *European Journal of Operational Research*, *Journal of Supply Chain Management*, *International Journal of Production Economics* and *Mathematical and Computer Modeling*, and through talks at various academic conferences.

Sameer Prasad is a Professor of Operations/Supply Chain Management at the University of Wisconsin-Whitewater. His research interests lie in the areas of quality management, supply chain management and international operations management. Recently, he has been focusing on disaster mitigation, micro-enterprises and poverty alleviation. His research has appeared in a number of outlets including *Journal of Operations Management*, *Decision Sciences*, *European Journal of Operational Research*, *Omega*, *International Journal of Production Economics*, *International Journal of Operations and Production Management* and *International Journal of Quality and Reliability Management*, among others.

Jayavel Sounderpandian, 56, passed away in April 2007. He had been a Professor of Quantitative Methods in the School of Business and Technology at the University of Wisconsin-Parkside since 1983. He served as the Interim Dean in 2005–2006. He was the author of two books including a widely used statistics text book and of numerous publications in national and international journals. He was a recipient of the university's distinguished research award. His research in the area of risk and uncertainty appeared in a number of publications including *Operations Research* and *Omega*.

1 Introduction

Natural disasters can result in numerous deaths, extreme suffering and immense loss of property. To contain the loss and suffering, it is crucial to rush supplies and aid to those in need. Given that humans cannot survive without food, water, medicine and shelter for more than a few days, it becomes imperative to make relief supplies available swiftly and at short notice. In the long term, as populations gravitate toward desirable locations and their densities increase, the concern about disasters becoming increasingly severe is very real. That, in turn, makes better management of relief efforts even more critical (Inyang, 2000). Research by the Fritz Institute identified lack of recognition of the importance of logistics, inadequate use of technology and limited collaboration as some of the common challenges in humanitarian aid logistics (Thomas and Kopczak, 2005). Controlling procurement and flow of goods into the region is a critical part of this equation. According to Trunick (2005), approximately 80% of disaster relief effort is logistics.

The difficulty in providing supplies to the disaster zone stems from several issues. The time horizon to help the population in need is often very short and the distance to move supplies from their distribution centres is very long. To make matters worse, in most locations the transportation infrastructure is heavily damaged by the disaster. Alternative transportation mediums and shipping routes will have to be explored. Paucity

of critical information in disaster situations creates additional challenges. One does not immediately know the number of survivors and their immediate needs. Whatever information is available is still scattered at various levels within the logistics chain which makes it difficult to plan the relief operations. When a disaster crosses national boundaries, border controls and cultural differences add to the complexity. Sometimes, the sheer scale of the disaster demands the coordination of hundreds of relief agencies from around the world (Oppenheim et al., 2001). Finally, adding to the complexity and uncertainty is the dynamic situation on the ground with needs and resources constantly changing.

In this research, we first identify four stages of disaster management in relation to the logistics function. These are: strategic planning stage, preparation stage, pre-event stage and post-event stage. In the next section, we identify the tasks to be completed at each stage and the analytical techniques that may be applied. In the following section, we examine the disaster relief literature relevant to each stage. Finally, we show how supply chain management concepts are applicable at the strategic planning stage and elaborate on its details.

1.1 The four stages

The decisions to be made for disaster relief logistics are different at different stages. For example, at the strategic planning stage, the criteria for logistics vendor certification may be finalised. But when a disaster has just occurred, scheduling decisions have to be made in order to quickly deliver supplies to set of affected areas. We identify four stages of disaster relief planning and these are presented in Table 1. At each stage, the tasks that need to be carried out and the analytical tools that can be applied are listed. We review the various stages below.

Table 1 Tasks and tools for the four stages

Strategic planning stage
Tasks:
Determine community needs
Estimate disaster conditions (uncertainty, information quality, complexity)
Develop coordination plans
Improved communications (internally/externally)
Rationalise supply base
Investment in long term relationships and institutional memory
Set-up logistics vendor certification/selection criteria
Develop cross-functional teams
Encourage trust and commitment throughout the logistics chain
Finalise objective function for lower levels
Tools:
Supply chain management strategies

Table 1 Tasks and tools for the four stages (continued)

Preparedness stage
Tasks:
Selection of supply vendors
Selection of logistics support vendors
Selection of storage locations
Data collection
Scenarios and their probabilities
For each scenario
Demand distribution
Supply channel capacity distribution
Lead-times
Decisions:
Storage amount for each location
Supplies purchasing plan
Logistics support
Tools:
Stochastic optimisation
Pre-event response stage
Decisions:
Data collection about the event
Evacuation plans
Supply purchase plans
Shifting supplies among storage locations
Logistics plans
Tools:
Decision analysis
Post-event response stage
Tasks:
Data collection about damages
Demand locations
For each location
Demands for supplies
Priority/urgency
Available supply channels and capacities
Implementation:
Amounts of supplies to be purchased
Supply routing and scheduling
Tools:
Scheduling and optimisation

Stage 1 Strategic planning

This is the most important stage. Poor strategic policies can dissipate any potential benefits of significant preparation and pre/post event efforts. Hence, in this research we primarily focus upon strategic decisions. Decisions at this level then cascade down to the remaining stages. High level decisions are made in terms of potential community needs for vulnerable locations. Also, the degree of uncertainty, quality of information and degree of complexity is gauged. Based on these dimensions, it is possible to set coordination, integration and management policies of the logistics function. The objective function at the strategic level varies based upon the phase within a disaster. Given that some agencies work during multiple phases of a disaster, the objective function might require balancing several dimensions simultaneously. For example, how much additional cost to open an extra storage location is justifiable at the preparation stage, if it is expected to increase the number of beneficiaries by a given percentage? Such tradeoffs can become even more sensitive when benefits to varied ethnic, religious and class communities are to be compared. Also, with an expected dynamic environment it is important that such realities are recognised at the strategic level and help planners prepare for such eventualities. The best way to handle these issues is to finalise them at the strategic planning stage in the form of guidelines, which cascade down to the respective objective functions in later stages.

Stage 2 Preparedness

The tasks that logically follow from the strategic plans are to select supply vendors, logistics support vendors and storage locations. These are to be selected not only based on the strategic plans made in the previous stage but also based on the possible scenarios of disaster. This means one needs to collect data on possible scenarios along with their probabilities. For each scenario, data must be collected about the demands that may arise in different regions affected by the disaster. The demands cannot be predicted with certainty and hence, a probability distribution will have to be fit to the demand patterns. Disasters will also destroy roads and railroads in an unpredictable manner. Thus, the distribution channels and their capacities can vary in each scenario. Additionally, data about the lead times for supply orders and additional purchases will also need to be collected. Taking into account all the data and the uncertainties, vendors, logistics support and storage locations must be selected. After that, optimal storage quantities of different supplies at each storage location, feasible distribution routes and minimum required fleet size must be decided. The appropriate technique for these plans is stochastic optimisation.

Barbarosoglu and Arda (2004) provided an excellent example of this. They modelled the distribution of first-aid supplies as a two-stage stochastic programming problem with recourse. Their model is a multi-commodity multi-model network flow model but demands for resources and network arc capacities and supply amounts at nodes are treated as random variables. Ozdamar et al. (2004) presented an alternative approach. They assumed supply availability is known for some periods ahead and demand can be forecasted but that they both vary with time. They developed a mixed integer programming formulation for a hybrid problem integrating the multi-period multi-commodity network flow problem with the vehicle routing problem. Finally, Hwang (1999) also took a hybrid approach and first used a clustering algorithm to find

which areas should be served from which supply points and then implemented a vehicle routing problem that minimised total travel distance.

Stage 3 Pre-event response

Some disasters can be predictable to a certain degree. In the case of hurricanes and wild fires for example, there might be time to take action to save lives and minimise damage. Possible paths of a hurricane or spread directions of the fire can be forecasted. A common and difficult task at this stage is evacuation. Evacuation operations are immensely expensive and cause significantly discomfort to a population. An incorrect evacuation decision is thus quite costly. On the other hand, failure to evacuate people when they should have been can be devastating and highly regrettable.

Stages 3 and 4 are also the durations in which the event conditions are mostly dynamic. The changing environment during a disaster should be taken into account and alternate scenarios should be generated and tested. Many decisions to be made at this stage therefore need to take into account the attitudes of the community towards risk, the pain of losses and the amount of regret from wrong decisions. A common technique used for making decision under such conditions is decision analysis. Clemen and Reilly (2001, pp.60–62) explain how decision analysis may be applied to this problem.

Stage 4 Post-event response

Post-event stage refers to the time period immediately following the occurrence of a disaster. The urgent tasks at this point are to deliver supplies and other forms of aid quickly to the affected people and limit further damages. This requires optimal resource allocations based on assessed needs. Thus, accurate and thorough needs assessment is crucial. According to the communication protocols established at the strategic planning stage data must be collected about the supplies and services needed at every location. Data about road conditions should also be collected to assess the capacities of each route. With these data in hand, optimal decisions can then be made about resource allocations, task assignment and scheduling.

Given that the environment is often dynamic, it is necessary to collect data and allocate resources, assignments and schedules frequently. The frequency of revisions would be based upon the guidelines set about at the strategic level.

Fiedrich et al. (2000) recognised that the search and rescue of survivors, stabilisation of remaining infrastructure to prevent secondary incidents and immediate rehabilitation of transportation lifelines have the most impact on the number of fatalities after an earthquake and developed a dynamic optimisation model for resource allocation that minimises fatalities. Batta and Mannur (1990) pointed out that in large emergencies multiple response units will be needed to satisfy the demand of an affected area and developed an appropriate location covering model for planning and preparedness. Brown and Vassiliou (1993) developed a hierarchical model that incorporates an integer programming formulation for task assignment and a linear programming formulation for resource allocation which are coordinated through a simulation model that allows real time decision support. Barbarosoglu et al. (2002) focused on the scheduling of helicopters and developed a hierarchical mixed integer programming model that allows multi-criteria analysis in the existence of conflicting objectives.

Once the survivors are found, transportation infrastructures rehabilitated, resources allocated and supply and demand sources identified, the problem then becomes the effective and efficient distribution of aid. Haghani and Oh (1996) modelled the problem of moving different commodities (e.g., medicine, food, clothing, parts, machinery, etc.) using multiple transportation modes from a number of origins to a number of destinations over a transportation network within given time windows. Clearly, these problems fit rather nicely within the operations research/management science (OR/MS) field. Altay and Green (2006) provide an extensive survey of OR/MS literature with regards to pre- and post-event disaster relief operations.

Next, we review the relevant literature in developing an integrated logistics model for disaster relief at the strategic phase.

2 Logistics of disaster relief

The Fritz Institute defines humanitarian relief logistics as 'the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people' (Thomas and Kopczak, 2005). This definition parallels the supply chain management concept as we know it today. The management of logistics for disaster relief is complex and information driven in an uncertain environment. Hence, investing into building reliable logistical chains for relief aid is critical.

2.1 Complexity

Disaster relief logistics is a complex task. The mere size of the problem requires the involvement of international agencies, military forces, local authorities and non-governmental organisations (NGOs) creating bureaucracy and communication, collaboration difficulties (Oppenheim et al., 2001). Locating and deploying appropriate skills and expertise and donor induced constraints for allocating resources inflate this complexity (Oppenheim et al., 2001).

2.2 Uncertainty and information quality

Disasters are unpredictable and often occur in developing countries with poor transportation and communication networks (Nollet et al., 1994). Routinely political constraints and domestic or international conflicts add more complications to the situation (Voordijk, 1999; Prater et al., 2001). Often, corruption and bribery add to the uncertainty of the operations (Hecht and Morici, 1993). Furthermore, for relief agencies the nature of funding is unreliable, there is a high employee turnover, a lack of institutional learning and operations are based on poorly-defined processes and disjointed technologies (Chomilier et al., 2003; Thomas and Kopczak, 2005).

As with corporate supply chains, availability and proper management of information seems to be one of the key success factors in humanitarian aid logistics. However, in most disasters, information is scarce and coordination rarely exists (Long and Wood, 1995). Efforts are duplicated; agencies often compete with each other for some of the same supplies and get taken advantage by opportunistic vendors.

Surprisingly for many aid agencies, ensuring reliable logistics has not been a main priority. Hence, the potential for increasing the efficiency and effectiveness of relief operations is significant. We can certainly draw upon the literature in operations research to help guide these agencies. But to understand all the complexities of a large scale disaster, it is essential to examine the international logistics chains.

2.3 International logistics chains

Supply chains are inter-organisational networks with an environment characterised by many uncontrolled forces and complexity (Peck, 2005). These networks need to be flexible to account for the unpredictability in the international environment and the sheer type and scale of disasters. 'Natural catastrophes are classed as great if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary.' (Major Natural Catastrophes, 2002). Prater et al. (2001) point to the following international factors in disaster management: geography, political/legal, social/cultural and development level. Other critical contextual factors include organisational networks and population density (Inyang, 2000). Naturally, the logistics systems need to be flexible enough to account for these factors.

2.4 Integrated supply chain model

Chen and Paulraj (2004) identify three seminal constructs influencing supply chain network: environmental uncertainty, information technology/quality and customer focus. The corresponding logistic support network can be defined by the degree of coordination, integration and supply management. Specifically, supply management includes issues such as communications, supply base reduction, long term relations, supplier selection/certification criteria, cross-functional teams and trust and commitment. The performance of the network can be measured in terms of both, financial and operational variables including critical time-based ones.

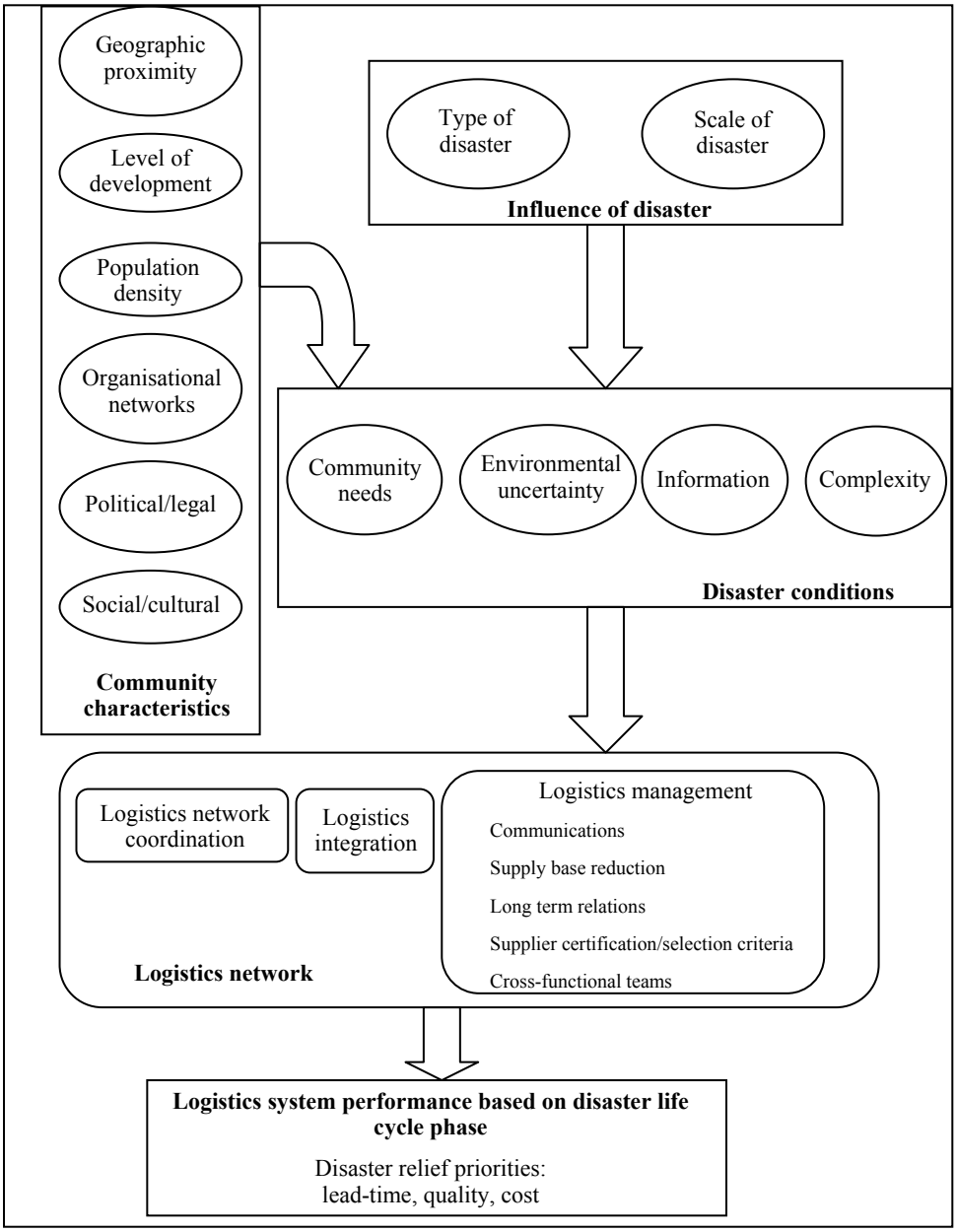
Time-based measures are particularly of value in disaster management, which can also be adapted from the for-profit world. Time related concepts include agile supply chains (Christopher and Towill, 2001), quick response, the design logic of flexible manufacturing systems, postponement strategies and modular design. Given the uncertainty of a disaster, relief agencies need to be agile enough to adapt to the new and often changing circumstances. As disasters evolve, the needs also change to satisfying survivor needs and managing costs.

Table 2 Performance characteristics of the logistics network during post-event response

Response phase	*Relief*	*Recovery*	*Reconstruction*
Time marker	Initial days after incident	After the evaluation of agency scouts	Months after the media interest faded
Type of network	Agile	Lean/agile	Lean
Priorities	Lead-time	Quality	Cost
Performance metrics	Market share throughput time	Throughput time customer satisfaction	Customer satisfaction financial measures

Christopher and Towill (2000) discuss the evolution of the personal computer supply chain. They identified the PC supply chain to be product driven in the early 1980s (phase I), market oriented in the late 1980s (phase II), market driven in the early 1990s (phase III) and finally customer driven in the late 1990s (phase IV). Disaster relief aid agencies go through similar stages of this transition within just months, only to start all over again after a new incident (Table 2).

Figure 1 Integrated logistics model for disaster relief



3 Toward a theory of integrated logistics for disaster relief

In this research we borrow a theoretical framework from the supply chain management literature and apply it towards international disaster relief. In supply chain management the focus is towards coordinating upstream activities, with operations in the midstream to satisfy demands downstream. The logistics model (Figure 1) in our research will only focus on the connections between the midstream suppliers and the downstream needs.

3.1 Logistics network performance

In this research, we adapt Christopher and Towill's (2000) supply chain evolution to disaster relief life cycle (Table 2). Once a disaster strikes the logistics network is oriented in simply providing the critical supplies (food, water, medicines) with a minimum of a lead-time to those in need. For example in 'less than 24 hours after the widespread tsunami struck South Asia, the US military mobilised its forces for the huge recovery operation, drawing the Defense Logistics Agency for support and supplies to aid the injured and homeless and even attending the deceased' (Katzaman, 2005). At this time the corresponding metrics would be the number of people reached (market share) and the throughput time. After the agencies evaluate the community needs, the focus becomes the quality of services provided to the community (Long, 1997). The corresponding metrics include the throughput time and customer (survivor) satisfaction. To ensure the quality services, the network has to be somewhat adaptable and effective in meeting the survivor needs. Thus, the network is a hybrid between agile and lean forms. Finally, at the reconstruction phase, the focus becomes on costs effectiveness in meeting the donor needs. Hence, the performance metrics are financial measures and customer satisfaction. A lean logistics network can accommodate such needs.

Borrowing from Chen and Paulraj (2004) supply chain model, the network can be defined in terms of the logistics coordination, integration and management (Figure 1). The demands placed on the network structure is a function of the community needs, degree of uncertainty, quality of information and complexity for the various phases of the disaster life cycle. These are influenced by the disaster (type and scale) and the characteristics of the region it strikes.

3.2 Influence of disaster

There is a wide range of disasters from man-made chemical spill to natural disaster such as tsunamis. The severity of the event can be marginal with only a few injuries and minor damage to massive destruction with fatalities in the thousands. The type and scale of a disaster interacts with the regional characteristics to affect the community needs (type and quantity of supplies), the degree of uncertainty, quality of information and the level of complexity that relief agencies need to deal with. For example, the Indian Ocean tsunami affected 12 countries, killing approximately 240,000 people and displacing more than a million. Considerable and continuous aftershocks in the region has caused further death and damage and slowed recovery efforts. The relief effort to the region consists of food, clean water, sanitation equipment and medicine. The terrorist attacks to the World Trade Center or the train explosion in North Korea on the other hand, required a much different response in nature and content of relief.

3.3 Community characteristics

3.3.1 Geography

Distribution and transportation requirements differ dramatically around the world (Long, 1997). Different regions in the world have characteristics that hinder or exacerbate relief operations. Communities that are in remote regions get quickly isolated and supplies need to travel great distances often with little or no infrastructure remaining. For example, in India the tsunami affected the remote Nicobar Islands and the costal regions of Southern India. A year later, most of the costal regions on the mainland have been rebuilt, but the Nicobar Islands still lack some of the basic infrastructure.

3.3.2 Level of development

The level of development generally translates to a more developed transportation, communication and human resources infrastructure. In many developing regions of the world such infrastructure is weak to begin with and gets quickly overwhelmed when disaster strikes.

3.3.3 Density

Population density is a critical dimension for disaster relief. In densely populated regions the number of fatalities, injuries and destruction tend to be greater on per square kilometre basis (Major Natural Catastrophes, 2002; McNeill, 2005).

3.3.4 Organisational networks

A community is defined by the various type of supporting organisational networks including NGOs, local/federal administration and even the military. NGOs can take preventative actions, identify needs at a local level and distribute supplies effectively. Government agencies also can play a crucial role in coordinating the distribution process. Finally, the military units have sophisticated logistical expertise designed especially for an emergency environment (Brown and Vassiliou, 1993; Long, 1997). Regions with weak organisational networks are often unable to cope at a time of disaster. For example in Indonesia the ‘relief agencies brought balance as they took over the operations, but found they had to rely on the military since the administrative infrastructure had been wiped out and the only organised governing body in the region was the military’ (Trunick, 2005).

3.3.5 Social/cultural

Values and beliefs of communities affected by disasters have to be respected in terms of form of distribution and the type of supplies. Hence, distributing rations laced with pork extract would be counter productive in predominantly Muslim regions. Some cultures are more open to outsiders and have fewer differences in terms of gender roles. The more tolerant cultures place fewer specific demands and can provide higher quality of information to relief managers.

3.3.6 Political/legal

Societies with a free press and a democratic system in place tend to ensure a more even and equitable distribution of supplies. A free press generally ensures a higher quality of information on the disaster conditions. In a democracy, officials held accountable for their duties are more likely to respond to the community needs. In addition, a democratic system allows for the growth of a range of administrative bodies that can play a role in disaster relief.

3.4 Disaster conditions

In Figure 1, the input that is dynamic during the onset of a disaster and shortly thereafter are the disaster conditions. The type of disaster conditions faced by relief organisations can be identified by community needs, degree of uncertainty, quality of information and complexity.

3.4.1 Community needs

Community needs consists of food, tents, clothing, medicine, serum and search and rescue equipment (Ozdamar et al., 2004). In general, the more severe the disaster the greater the needs; these needs are amplified in remote third world regions with high population densities with weak organisational networks. Communities that are ruled by autocratic dictators and conservative societies are particularly vulnerable, requiring additional resources.

3.4.2 Degree of uncertainty

The form and intensity of a disaster will affect the degree of uncertainty. 'Moreover, the damage of the supply and service providers that are also directly subjected to the effects of an earthquake naturally randomises the availability and usability of commodities; consequently it should be kept in mind that the whole transportation system is vulnerable and may be totally unoperational' (Barbarosoglu and Arda, 2004). In addition, the regions that are remote, less developed, densely populated, with limited community networks and closed political system tend to generate greater uncertainty.

3.4.3 Information technology

'Information systems have suffered from a lack of investment in part because of a contradiction of priorities. Relief agencies are judged by the percentage of their funds used on relief supplies and those agencies that spend the least on overhead are often considered the most efficient. Thus, agencies are reluctant to spend money on complex information systems' (Long, 1997). Unfortunately, in most remote locations, communication infrastructures are either underdeveloped or neglected and lack of established organisational networks to provide accurate information. Moreover, information may be filtered or censored in regions with autocratic and/or corrupt governments.

3.4.4 Complexity

In a large disaster, 'hundreds of institutions worldwide play a role in emergency relief operations and the lack of inter-organisational coordination is becoming a major impediment as institutional rivalries takes priority over logistical efficiencies' (Long, 1997). Given the distributed nature of relief operations and the number of parties involved, the problems become quickly complex. But more importantly, the majority of the constraints in logistical problems during disaster relief are not 'hard' constraints (i.e., mathematically modelling them is difficult). Armed conflicts (e.g., separatist rebels in Banda Aceh or insurgency attacks in Iraq), human rights violations (e.g., abduction and rape of women and children in Darfur) and political or ideological attitudes towards relief (e.g., North Korea's block to relief shipments from South Korea during the response to the April 2004 train explosion) all add constraints to the problem that are difficult to model.

3.5 Supporting logistics network

The disaster conditions defined by the community needs, degree of uncertainty, quality of information and the complexity, need to be managed by the logistics network in order to yield the necessary performance outcomes outlined earlier. Such a network needs to be flexible enough to respond to the changing environment and consists of three critical dimensions: logistics coordination, logistics integration and logistic management.

3.5.1 Logistics coordination

A key issue in disaster management is searching for a way to achieve unity of efforts and better coordination across the variety of organisations (Bui et al., 2000). A number of international agencies and domestic agencies have spearheaded this effort. For example, the UN (Cottrill, 2005) and World Economic Forum (Trunick, 2005) have attempted to set up logistics coordination hubs. Specifically, the United Nations Joint Logistics Center (UNJLC) has taken on the challenge to coordinate large relief efforts by collaborating with various aid agencies, governments and local authorities around the world. UNJLC views the disaster relief effort as a 'modular' system and seeks to strengthen logistics of individual agencies. It accomplishes that by gathering, collating, analysing and disseminating relevant information from and among humanitarian and non-humanitarian actors (Kaatrud et al., 2003). Also, the World Food Program (WFP) has established strategic response warehouses to cover the four quarters of the world. These locations not only provide storage capacity but also serve to coordinate response. National agencies have also setup coordinating systems. For example, the Defense Distribution Center in New Cumberland, Pennsylvania, coordinated distribution depots in San Joaquin, Pearl Harbor and Yokusuka, Japan, for the tsunami relief operation on behalf of the USA Government (Katzaman, 2005). Unfortunately, a report to the UN's Economic and Social Council (ECOSOC) states that coordination was not always smooth during the response to the Indian Ocean tsunami. Some communities were flooded with relief items and the items did not always match the needs. Miscommunication among aid agencies led to duplications of efforts, delays and ad hoc plans (ECOSOC, 2005).

Fortunately, we can draw upon the corporate literature and experiences (Levick and Smith, 2005) to provide direction to disaster management. One of the goals of

coordination is to optimise relative to the various performance objectives with procurement and distribution functions spanning across multiple locations and countries. Internally, the coordination has to include not only the parties directly involved with logistics but also with any related functional areas that support the logistics. Externally, the coordination has to encompass all parties affected or involved with the relief operations. Literally, this may mean coordinating with hundreds of parties. The literature also notes the role of coordination in relationship to the bullwhip effect as described by Forrester (1958). This bullwhip effect naturally emanates on account of uncertainty and quasi-independent decision making along the chain. It would be potentially valuable to study techniques developed to minimising oscillations in commercial enterprises to relief operations.

Corporate experiences also point to the value of protocols in the coordination function while responding to disasters (Levick and Smith, 2005). These protocols are useful in improving logistics integration and management.

3.5.2 Logistics integration

In large scale disasters, the need for integration quickly becomes apparent. For example, after the tsunami, 'some of the supplies slowly filtered out of those in need, but much remained painfully out of reach at airports strained by the sudden influx of flights, ill-equipped even to load off planes and unreachable by conventional transport' (Hoffman, 2005).

The literature provides some direction in improving the performance of the supply chain. One way to increase throughput along the chain is by integrating internally with supporting functions and externally with collaborating parties. Internal measures revolve around reducing organisational slack, by integrating across various functional areas within the relief agency. For example, International Federation of Red Cross and Red Crescent Societies' Logistics and Resource Mobilisation Department (LRMD) has worked to expand their focus from merely purchasing of relief goods to include all activities such as planning, warehousing, training and reporting (Chomilier et al., 2003). As with the corporate world, the benefits of internal integration lie in developing the logistics process as an integrated system rather than simply optimising functional sub-systems (Kent and Flint, 1997). A mechanism to integrate these diverse elements has been developed by the Fritz Institute (http://www.Fritzinstitute.org) modelled after enterprise resource planning (ERP). Based upon the concept of a common database system, the Humanitarian Logistics Software (HLS) integrates diverse aspects of the logistic function.

Today, the corporate world has expanded the logistic integration with external partners. Likewise, disaster relief agencies have moved in this direction. For example, the Defense Energy Support Center (a sub-function of the Defense Logistics Agency in the USA) relied on external integration with a local fuel company to increase capacity and truck deliveries to Banda Aceh (Katzaman, 2005). To improve logistics coordination it is important to standardise procurement, transportation and tracking of relief goods along with codes of conduct and frame agreements. Finally, for the logistics coordination and integration to yield the desired performance, it is crucial to manage the logistics chain effectively.

3.5.3 Logistics management

Multilateral and relief agencies have recognised the value in managing logistics properly and have experimented with a multitude of approaches. For example, WFP has invested in pre-fabricated pre-wired facilities, a logistical preparedness team called Augmented Logistics Intervention Team for Emergencies (ALITE), an information and communications technology support team named Fast Information Technology and Telecommunications Emergency Support Team (FITTEST) (Scott-Bowden, 2003). However, the literature does not systematically identify critical elements of logistics management in relation to disaster relief. Hence, we need to borrow concepts established in the corporate world. Key dimensions in logistics management for the corporate world include: improved communications, supply base reduction, long term relationships, supplier certification/selection, cross-functional teams and trust and commitment. Next, we will examine how these specific dimensions apply to disaster relief, recovery and reconstruction.

3.5.4 Communications

To drive material along the logistics network it is critical that communication occurs effectively within the agency and with its external partners. Unfortunately, relief agencies most of the time are neither funded well enough to support new communications technology nor have the sophistication to use information technology effectively (Long, 1997). In addition, when disaster strikes, communication infrastructure breaks-down, making it even more difficult to accurately gauge the situation (Hoffman, 2005). Finally, translation problems crop up as relief workers often come from different countries and speak different languages (Long, 1997).

Although, agencies need to invest heavily in communications equipment (Heinmiller, 2002), the literature also indicates that management related issues play an important role in improving the logistics chain performance. Research shows that two way communications with both internal and external parties is critical for successful logistics (Krause, 1999). In particular, the frequency of interactions and the relationships among diverse parties in trying to come up with a solution are critical for communicational effectiveness. Given that relief operations are dependant on literally hundreds of parties, it makes sense to reduce the number of vendors and freight forwarders in order to have more frequent communications and develop long term relationships.

3.5.5 Supply base reduction

Taking a page from research relevant to the corporate world, disaster relief agencies need to reduce complexity by decreasing the number of suppliers. A reduction in the supply base reduces both holding and transaction costs, reduces lead-times due to dedicated contracts, reduces logistics and coordination costs (Chen and Paulraj, 2004), leading to better performance results. There is very little evidence however, that relief operations have actively reduced their supply base. Based upon the benefits documented in the corporate world, we suggest that agencies develop protocols to reduce the number players involved with logistics. Specifically, with fewer suppliers it might be possible to apply postponement strategies in order to be more responsive (Fisher, 1997) and ensure modular designs. Given the seemingly chaotic operating environment in disaster

management, it would be interesting to correlate logistics base reduction with improvement in the performance measures for the various phases of a disaster life cycle. However, with fewer parties it is crucial they are indeed reliable and open to long term relationships.

3.5.6 Long term relations

Unlike the corporate world where the logistics patterns are repeated on a systematic basis, in disaster management, the needs frequencies of replenishments and location are never the same. The logistics chain gets created for a specific disaster and quickly dissipates at the end of the reconstruction phase. It has been recognised the near total absence of institutional memory from one disaster to another (Hoffman, 2005). Thus, relief organisations have attempted 'to maintain a core of expertise that can help raise the level of effectiveness of relief efforts as they continue in response to events large and small around the world' (Trunick, 2005).

Long term relationships have become critical today for supply/logistics chains (Shin et al., 2000). Long term relationships promote sharing of risk/benefits with vendors and helps develop institutional memory that is lasting. For example, WFP's effort in developing long term supplier relations has led to rapid local procurement capability allowing them to significantly reduce inventory levels (Scott-Bowden, 2003). Although, setting up these long term relationships initially requires upfront investments, they more than payoff in terms of reduced transaction costs and self-enforcing safeguards to control opportunistic behaviour (Dyer, 1997).

Potential research in linking the effect of long term relationships with mediating variables such as shared risk/benefits and intuitional memory on performance metrics at the various life cycle phases of disaster management would be worthwhile. The results of such a study would certainly be of value to relief agencies.

3.5.7 Supplier certification/selection criteria

In developing and investing in long term relationships, it is essential that the logistics vendors are carefully selected. To ensure that the various performance metrics are met and opportunistic behaviour is minimised, it becomes imperative to have some methodology to identify preferred suppliers in disaster management (McClintock, 2005). For example, the application of the ISO 9000 standard for supplier certification has been suggested (McClintock, 2005). Other approaches to certification can also be drawn from the corporate literature. Certification requires extensive investigation of logistics vendors to gauge motivation and capabilities (Gibson et al., 1995). Once certified, vendor supplies and support functions are accepted without routine testing of each receipt (Baiman et al., 2000).

Research from the corporate sector indicates that the focus of supplier certification needs to be based upon quality, lead-times and reliability (Ellram, 2001) rather than simply cost (Croom, 2001). Naturally, it would be of value to define and study supplier certification criteria for the logistics function in disaster management. Finally, to meet the respective performance metrics for the various phases in a disaster's life cycle, it is critical that the logistics partners are all aligned towards the same customer needs (lead-time, quality and cost). This requires a certain degree of commitment and trust on

the part of the agency and vendors. In addition, it requires that within the agency cross-functional teams are developed.

3.5.8 Cross-functional teams/trust and commitment

The literature on developing and managing cross-functional teams in disaster management is quite limited. It has been noted, that many of the organisations involved in disaster relief operate as competitors with each other in trying to demonstrate their uniqueness to garner public support. This leads to mistrust, misrepresentation of facts and incomplete information exchange among participants (Bui et al., 2000). Bui et al. (2000) adds that 'it is often difficult for the participants to cooperate even without competition. Even when individual rescuers from different agencies are willing to cooperate, the organisational, legal, bureaucratic and budgetary constraints hinder cooperation. These constraints often prevent harmony among participants and timely execution of missions'.

This silo mentality and bureaucratic barriers have been well documented in the corporate literature. One of the critical elements of total quality management (TQM), reengineering and other organisational transformations has been to develop cross-functional teams. Hence, it would be possible to apply TQM methodologies in managing cross-functional teams to yield the desired performance objectives at various phases of a disaster life cycle.

Cross-functional teams and long-term relationships only flourish when there is trust (Heide and John, 1990) and commitment among all partners. Trust imbues when agencies are confident with their logistics vendors and the partners do not exert opportunistic behaviour (Chen and Paulraj, 2004). Commitment revolves around logistics partners' willingness to sustain long-term relationships and that the respective performance priorities are met. A committed and trustworthy logistics network would be instrumental in meeting the necessary demands at the time of relief, recovery and reconstruction.

4 Conclusions

In this research, we examine the various stages of disaster management in terms of the logistics function. The literature indicates that it is imperative to put primary effort at the strategic level. Relief agencies operating at a strategic level need to be cognisant of the community characteristics and potential forms of disasters, while identifying community needs, the degree of uncertainty, quality of information and complexity. To ensure the corresponding performance objectives are met at the various phases of the disaster relief life cycle (lead time, quality and cost) agencies need to coordinate, integrate and manage their logistics function appropriately. Specifically, in terms of management function it is important to improve communications with both internal and external parties, narrow the supply base, invest in long-term relationships, setup supplier certification specifications, develop cross-functional teams and promote trust and commitment throughout the entire logistical chain. Decisions at this level then cascade down to the preparation and pre/post event response stages.

One difficulty in managing disasters is that the underlying ground situation is constantly changing. In this research, it is suggested that agencies develop guidelines on the frequency of review prior to the advent of a disaster. Perhaps researchers in the future might want to explore the frequency based upon the type/form of disasters and the level

of development (developed vs. developing regions). Also, it might be possible to develop dynamic mathematical models to optimise the allocation of resources and schedules in stages 3 and 4 of Figure 1.

As part of the integrated logistics model for disaster relief developed in this study, we have identified specific topics that would be worthwhile for researchers to pursue. In addition, we have provided specific recommendations to relief agencies that can be immediately implemented.

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