

Emergency Logistics Issues Affecting the Response to Katrina

A Synthesis and Preliminary Suggestions for Improvement

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Extreme events pose serious logistical challenges to emergency and aid organizations active in preparation, response, and recovery operations, because the disturbances they produce have the potential to turn normal conditions suddenly into chaos. Under these conditions, delivering critical supplies (e.g., food, water, medical supplies) becomes an extremely difficult task because of the severe damage to the physical and virtual infrastructure and the limited or nonexistent transportation capacity. In this context, the recovery process is made more difficult by the prevailing lack of knowledge about the nature and challenges of emergency supply chains. As a result, the design of reliable emergency logistics systems is hampered by lack of knowledge about how formal and informal (emergent) supply chains operate and interact; methods to analyze and coordinate the flows of priority and nonpriority goods; and, in general, scientific methods to analyze logistics systems under extreme conditions. This paper describes the key logistical issues that plagued the response to Hurricane Katrina. The logistical failures following Katrina, which in August 2005 devastated the U.S. Gulf Coast, provide an example of the need to improve the efficiency of supply chains to the site of an extreme event. The paper is based on public accounts of the event and interviews conducted during a number of field visits to the Katrina-affected area in the aftermath of the event, as part of a research project funded by the National Science Foundation.

Extreme events pose serious logistical challenges to agencies and aid organizations active in response and recovery operations because these disruptions typically have a significant impact on emergency supply chains. Under these conditions, delivery of critical supplies (e.g., food, water, medical supplies) is an extremely difficult task due to severe damage to the physical and virtual infrastructure and the limited or nonexistent transportation capacity in the affected areas. Surprisingly, not much research has been conducted on the subject of emergency logistics. As a result, the design of reliable emergency logistics systems is hampered by a lack of knowledge about how formal and informal (emergent) supply chains operate and interact; methods to analyze and coordinate the flows of both priority and non-

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priority goods; and, in general, scientific methods to analyze logistics systems under extreme conditions. This is important because, since 1989, the United States has frequently entered periods in which catastrophic natural disasters have generated losses that averaged approximately \$1 billion per week, and this trend is expected to continue (1, 2). In this paper, the key logistical issues identified during the preparation and immediate response to Hurricane Katrina, which devastated the U.S. Gulf Coast in August 2005, are described. The analysis is based on interviews conducted with staff from government agencies, nongovernmental aid organizations, and volunteer groups as part of an ongoing project sponsored by the National Science Foundation.

MATERIEL CONVERGENCE AND EMERGENCY LOGISTICS

For the most part, supply chain research focuses on the commercial supply of goods and services; it rarely discusses emergency logistics. The social science disaster literature has examined institutional arrangements and multiorganizational responses to extreme events, but little attention has been given to the impact of such arrangements on logistics. This suggests the need for multidisciplinary research that addresses the problem by using both social science frameworks and transportation modeling techniques. A multidisciplinary perspective promises to overcome the unique challenges of emergency logistics, characterized by (a) large volumes of critical supplies to be transported, (b) short time frames of response to prevent loss of lives and property, and (c) major uncertainties about what is actually needed and what is available at the site.

As explained by Beamon (3), the response to disasters generally evolves through four stages (assessment, deployment, recovery, and reconfiguration), each with distinctive sets of needs and objectives. Social science research has long asserted that the occurrence of an extreme event triggers a massive influx of personnel, information, and materiel to the affected site. The phenomenon was discussed, for example, in the first sociological study of a disaster: S. H. Prince's investigation of the Halifax munitions ship explosion in 1917 (4). In a seminal report, Fritz and Mathewson (5) presented perhaps the earliest comprehensive treatment of the subject and provided the first comprehensive taxonomy of the components of this influx. They defined *convergence* as "movement or inclination and approach toward a particular point." They outlined three basic components of convergence: personnel convergence (i.e., the movements of individuals), informational convergence (i.e., "the movement or transmission of symbols, imageries, and messages"), and materiel convergence (i.e., "the actual movement of supplies and equipment") (5, p. 4).

Convergence behavior has been identified in almost all extreme events. Unfortunately, the amount of scholarly research is not yet commensurate with the importance of this topic. This point was emphasized by Scanlon (4), who stressed the lack of research on convergence. Some of the few publications [e.g., that by Kendra and Wachtendorf (6)] have focused on, mostly, people convergence. While the topic has been addressed peripherally in other research discussions (6–8), a paper by Neal (9) is among the few research publications dealing exclusively with materiel convergence.

Despite the scarcity of research, materiel convergence is an important topic because of its significant and complex interactions with the delivery of high-priority supplies to the site of an extreme event. As has been observed during recent disasters such as the attack on the World Trade Center in 2001; the Asian tsunami in 2004; and Hurricanes Katrina, Rita, and Wilma in 2005, unsolicited donations may cause unexpected problems to the logistics system supporting the relief and recovery operations. Although donations can be helpful in certain circumstances, much of the material provided is inappropriate given emergent needs, donated at inappropriate times, or in great excess of what is required. Consequently, superfluous donations require the expenditure of considerable resources to manage or dispose of them. This insight was confirmed by a survey of logisticians from the largest international organizations active in the relief efforts of the areas affected by the 2004 Asian tsunami (10). The survey concluded that the process of identifying, prioritizing, transporting, and storing unsolicited donations that were delivered directly to disaster areas required valuable resources and had a detrimental effect on recovery activities.

THE RESPONSE PROCESS AND ITS KEY PARTICIPANTS

Responders to disasters can generally be classified into four groups: government agencies, volunteer organizations, the private sector, and individual citizens. The heaviest burden and responsibility for planning and executing the response to extreme events usually reside in government agencies (including the military) at local, state, and federal levels.

Volunteer organizations include a wide spectrum of entities ranging from local civic and faith-based groups to large international organizations. Examples include the American Red Cross, Cooperative for American Relief Everywhere (CARE), Doctors Without Borders, and the Salvation Army. These organizations usually play critical roles during disasters and provide basic human and medical services. National, regional, and local Voluntary Organizations Active in Disasters (VOAD) chapters also contribute to a coordinated response to emergencies by promoting information exchange among nonprofit aid organizations to avoid duplication of effort.

Private-sector responders range from small businesses to multinational corporations. The private sector may make important contributions through cash and in-kind donations and provide professional services in highly specialized areas such as logistics and information management. Materiel contributions from individual households are usually smaller, though collectively they may reach large amounts. Citizens—both locals and convergent from outside the affected area—may play an active role in the response by engaging voluntarily, for example, in search and rescue activities. Often these converging individuals bring goods with them to the disaster area.

Coordinating the activities of responders operating under different organizational structures and with different professional backgrounds,

and priorities is a highly complex task. In the United States, that coordination is defined by the National Response Plan (NRP), which provides a single, comprehensive, and all-hazards approach for the management of high-impact domestic emergencies [i.e., incidents of national significance (INS)]. The NRP specifies how federal government resources will coordinate with state, local, tribal, private-sector, and nongovernmental organizations to respond to an INS. The NRP is based on the National Incident Management System, which was developed so that responders at all levels could coordinate in a unified response, and can be partially or fully implemented in the context of a threat of, anticipation of, or response to a significant event. The NRP is based on the idea that local authorities are the first responders to any emergency and that they look for help to the state and neighboring states when overwhelmed. Federal assistance comes into play once those resources are overwhelmed. State emergency plans are also based on this hierarchical system. For example, Louisiana's Emergency Operations Plan specifies that local governments should exhaust their own resources before requesting outside aid.

The Federal Emergency Management Agency (FEMA) is responsible for coordinating federal assistance for disasters. FEMA is a relatively small agency that manages the federal response and recovery efforts. It does not provide operational support because it does not have physical assets. Instead, FEMA tasks other agencies to perform specific operations. FEMA serves as the main contact to the federal government for state and local authorities. As part of a pull system, when a state makes a request to FEMA, the agency tasks other federal entities to fulfill the request. The federal government then delivers the assistance to the state, and the state is responsible for making that assistance available to those in need.

A catastrophic incident is a scenario under which local and state governments are overwhelmed to the point of not being able to use the "pull" system. Only the federal government can respond and restore order after the occurrence of such a disaster. The NRP considers this possibility in the Catastrophic Incident Annex, which switches the federal response to a "push" system whereby the federal government actively "pushes" resources to the affected area without waiting for state requests. At the time this paper was written, this annex was still in its draft version and had not been promulgated.

THE EMERGENCY IN BRIEF

Hurricane Katrina was the first Category 5 hurricane of the 2005 Atlantic hurricane season and, at its peak, the sixth-strongest storm ever recorded in the Atlantic basin (11). It first made landfall as a Category 1 hurricane north of Miami, Florida, on August 25, 2005, before strengthening rapidly in the Gulf of Mexico to a Category 5 hurricane. The storm weakened considerably before making its second landfall in southeast Louisiana, Mississippi, and Alabama as a strong Category 3 storm on the morning of August 29th with sustained winds of 145 mph and gusts of 215 mph. Katrina continued to affect the central region of the United States as it moved north from New Orleans, Louisiana. Katrina was last acknowledged as a hurricane near the Great Lakes on August 31, 2005, when it disintegrated in southeastern Canada.

Katrina caused devastation over 100 mi away from the storm eye-wall, leading to property damage ascending to \$96 billion (12, p. 7) and making it the most destructive natural disaster in U.S. history. It is estimated that its total economic impact may reach \$200 billion. Katrina was also one of the deadliest hurricanes ever to hit the U.S.

mainland, with 1,577 confirmed casualties and 226 people still missing as of May 2006 (13). Gulf Coast communities in Louisiana, Mississippi, and Alabama were devastated by the storm's powerful winds. Katrina's surge also breached the levees protecting New Orleans, ultimately flooding roughly 80% of the city and many areas of neighboring parishes. The government issued federal disaster declarations for 90,000 mi² of the United States, an area almost the size of the United Kingdom.

RESEARCH PROCESS

This paper presents initial findings from an ongoing National Science Foundation project. The main objective of the project is to produce a formal characterization of the supply chains that emerged in the Gulf Coast before and immediately after the landfall of Hurricane Katrina. The investigators have approached the topic from a unified multidisciplinary perspective involving state-of-the-art thinking in both the social sciences and transportation engineering through a partnership between the Rensselaer Polytechnic Institute and the University of Delaware's Disaster Research Center.

Findings are based on data collected from 22 interviews with key organizational actors from local, state, and federal agencies, the private sector, and nongovernmental aid organizations and volunteer groups. Interviews were conducted during visits to affected areas in Louisiana and Mississippi in December 2005, January 2006, and March 2006. All respondents were active in the handling or distribution of critical supplies along the Gulf Coast, thus providing firsthand information based on their own experience and perception of the relief and recovery activities. In-depth face-to-face and telephone interviews focused on the dynamics of the supply chains, the procurement process, challenges, and lessons learned, among other topics. In addition to the interviews, the team studied public accounts of the event, with special attention to the official reports (12, 14, 15).

In all cases, the authors have respected the wishes of the respondents in terms of confidentiality. Therefore, the findings are presented without disclosing the identity, specific affiliation, or any other information that may compromise the confidentiality of the interviewee. Respondents from government agencies are only identified by their scope of responsibility (local, state, or federal). Respondents from voluntary and nonprofit organizations are referred to as "volunteers."

ISSUES IN THE RESPONSE TO HURRICANE KATRINA

The Katrina response has been widely discussed in different forums. Criticism of the government response is widespread; even the official reports (12, 14) recognized that there are many lessons to be learned from the response to this emergency. Although the devastation caused by the storm has raised many public policy questions about emergency management, environmental policy, poverty, and unemployment, the most pressing questions focus on the ineffective logistical response. The following subsections discuss the key issues identified during the research.

Magnitude of the Requirements

Almost all participants in the response to this disaster have pointed to the magnitude of the devastation as a key factor in the logistics failures, since Katrina was the largest natural disaster in U.S. history (12,

p. 5). Interviews with local and state officials suggested that volunteer organizations as well as government organizations were challenged by the disaster's size and corresponding requirements. For example, one local respondent stated, "I don't think Red Cross ever had to work with so many outside agencies in coordination." The American Red Cross (ARC) started preparing for Hurricane Katrina and deployed significant materiel resources to the Gulf Coast several days before landfall. The organization considered its prelandfall operations a success, since it was able, in a short time frame, to preposition 500,000 meals ready to eat, identify 15 sites for large kitchens to be used for mass feeding, open several shelters in the region, and deploy vehicles and staff to the disaster area (14, p. 69). ARC raised donations in excess of \$2 billion, or two-thirds of the total collections by charitable groups, and led the efforts of 220,000 staff and volunteers (14, p. 343). However, after the flooding of New Orleans, the number of victims requiring services from ARC grew faster than what the agency's logistics could support, and it experienced great difficulties in meeting needs for food and shelter. The organization received substantial public criticism for not having a logistics system robust enough to respond efficiently to the disaster. Its president resigned in December 2005.

Some critics to the immediate response and recovery activities have argued that the government lacked plans for a catastrophe that had been anticipated for years. Disaster plans in place did not realistically consider the requirements and consequences of an event like Katrina. According to one local official, "[Our] disaster preparation plan is a great checklist of everything that you have to do and it covers almost every type of emergency, except the one we had." A federal official also recognized the existence of such plans but pointed out that they were not executed during Hurricane Katrina: "The state of Louisiana has a super disaster plan. They have a donations plan. They have everything and it is on the shelf at the EOC [emergency operations center] and it was never taken off." The federal disaster response has received similar criticisms.

Collapse of the Communications Infrastructure

Hurricane Katrina severely damaged and made inoperable a significant portion of the communications infrastructure. Nearly 3 million people were left without electricity and telephone services, the 911 emergency call centers were severely affected, 50% of the radio stations and 44% of the television stations were out of service, and more than 50,000 utility poles were toppled in Mississippi alone (12, p. 55; 14, pp. 163-164).

The near total failure of regional communications created problems with agency coordination, logistics, and search and rescue operations (14, p. 165). After the loss of power and the collapse of the communications infrastructure, emergency responders did not have a reliable network to communicate and coordinate their activities within and between different organizations. According to one local official, "[The] entire infrastructure was wiped out [and] there were no communications . . . until 5 days after the storm [when] we got satellite phones." In some instances, local officials relied on only one or two satellite phones as their sole means of communication. One official indicated that for the hardest-hit areas during the immediate response, "the main communication came back and forth by helicopter. Sort of like a New Age Pony Express." Requests for supplies were literally written by hand, and officials had no knowledge of when or if those requests might be filled. According to another local, no one knew "if things had been delivered, and if they had been delivered, who accepted it." As such, you "get to the point where you have to commandeer supplies."

Of particular significance was the collapse of the Internet-based inventory system (E-Team) used by the state of Louisiana to process emergency requests. With computers under water and no power at the local parishes, local and state emergency officials lost a crucial component of the "pull" system intended to enable them to input their requests for emergency supplies. Local officials interviewed indicated that the E-Team service was reestablished 3 to 5 days after landfall. Thus, "supplies didn't go where they [were] intended to go . . . that was a huge issue."

Because of the loss of most means of communication, the media often became the only source of direct information in the immediate hours and days after landfall. Many field reporters became active participants in the response activities by sharing vital information between victims and authorities. As one volunteer stated, media can be helpful because if they "keep it [the needs] in the headlines, you get more donations." Parish officials confirmed that they strategically used the media to communicate their specific needs to the rest of the nation to avoid receiving unnecessary goods. However, in other cases the loss of the communications infrastructure compromised the level of situational awareness and led to inaccurate or unsubstantiated media reports, since officials did not have access to the facts to address or refute them.

For example, during the days after landfall, the media portrayed a picture of lawlessness in New Orleans, featuring stories about widespread looting, gunfire, murders, and sexual assaults, which eventually proved to be sometimes false and other times greatly exaggerated. Such reports created anxiety and fear among those in shelters, scared away truck drivers delivering critical supplies, and delayed the deployment and placement of government workers and volunteers. According to a state official, before Hurricane Rita, truckers were prestaged and told not to leave but "every single trucker left and went to Tennessee, Virginia, they went as far away as they could get" because of the reports of looting. According to another respondent, officials "had to stage truckers in reserve because they were scared to go into the city." Some reports suggest that many of the approximately 1,000 FEMA employees deployed and on their route to New Orleans on August 31, 2005, turned back because of security concerns (14, p. 157). In a similar manner, managers from several private companies and other organizations delayed deployment or removed workers and other resources from New Orleans to avoid exposing them to the risks and violence portrayed by the media.

Understaffing and Lack of Training

When Hurricane Katrina struck, FEMA was still undergoing a major reorganization as part of its integration into the Department of Homeland Security. FEMA had about 500 vacancies (20% of the 2,500 agency positions), with eight out of its 10 regional directors working in an acting capacity (14, p. 157). Understaffing was a difficult challenge for FEMA, which eventually turned to other federal agencies across the country to staff FEMA positions in Mississippi and Louisiana. The lack of adequately trained and experienced staff had a major impact on federal response operations.

In Louisiana, not all local officials were proficient in the use of E-Team (14, p. 322). Some FEMA employees assigned to local emergency operation centers were not familiar with E-Team either. In this case, the lack of proper skills made tracking the status of requests and deliveries more difficult.

Adequate staffing was also an issue for nongovernmental organizations. For example, although ARC had thousands of volunteers, most of them lacked experience or skills in complex logistics oper-

ations. The organization experienced problems with the distribution of supplies, and inaccurate inventory record keeping led to mismatches between the needs of victims and the supplies that were lined up (14). As one representative from a volunteer organization stated, "Every time a new group comes in, you have to train [them]." One local respondent articulated the need not only for "trained personnel" but for trained personnel who "are working and embedded in the parish on a regular basis."

Lack of Integration Between Federal and State Logistics Systems

While local and state governments used commercial software like E-Team for procurement and tracking, FEMA relied on a custom-made system, the National Emergency Management Information System (NEMIS). The two systems had no electronic interface between them (14, p. 325). Federal officials interviewed stated that the E-Team requests had to be read individually and input manually into NEMIS. State officials were unable to track their own requests once they were placed into NEMIS, and federal staff could not check information on particular requests originated in E-Team. Some local requests for federal assistance never reached FEMA and, consequently, were never fulfilled.

The lack of integration between systems delayed the response from FEMA and encouraged state and local officials to depart from FEMA's procedures for requesting supplies. In the middle of the crisis, FEMA fulfilled petitions without proper authorization and registration into NEMIS (14, p. 325). Thus, FEMA was unable to track these transactions, while errors were introduced into the inventory records. The agency probably did not identify discrepancies until it tried to use those resources to satisfy other requests, which further delayed its response.

Inefficiencies in Prepositioning Resources

Although state officials kept up to date with weather reports and requested supplies from federal agencies before Katrina made landfall, not enough supplies were prepositioned. An alternative explanation, gathered by the authors, suggests that the state of Louisiana did not preposition the critical supplies called for by its own emergency plan because it was waiting for the federal emergency declaration to avoid using state funds. To make matters worse, storage facilities had to contend with the double challenge of high winds and widespread flooding. A local respondent pointed out that "the problem with a hurricane, the two things that we had here were high winds and floods, so it's a Catch-22."

It is also telling that when it was announced that Hurricane Rita could strike New Orleans, state officials tried to preposition trucks with critical supplies. As mentioned earlier, to their dismay, upon hearing of Rita, almost all the truck drivers left the area with their trucks, rendering the attempt ineffective (the truck drivers were independent owner-operators under contract with Landstar, the company that has the contract with FEMA for trucking services).

At the federal level, FEMA started deploying supplies and other resources on August 28th after President Bush declared the federal emergency, just a day before the Katrina landfall (14, p. 320). Given the short time frame, FEMA was unable to preposition and deliver all requirements on time, and the activities were soon suspended because of the risks posed by the imminent strike of Katrina. It has also been argued that the selection of staging areas delayed the immediate

response, since some supplies were stored too far away from the affected areas (14, p. 320). Consequently, FEMA was still focused on procuring and deploying resources when it was expected to have those services already available to victims. Furthermore, the information gathered by the authors indicates that government officials at all levels failed to identify enough logistical staging areas, regional staging areas, points of distribution, and drop points, as well as to staff them immediately after the landfall. During interviews conducted for this project, local and state officials argued that the support from FEMA was extraordinarily delayed; in some cases supplies from FEMA were not received until 7 to 10 days after landfall. Another common concern was that the quantities of supplies received were significantly lower than the quantities requested (14, p. 321).

Lack of Planning for the Handling and Distribution of Donations

Government agencies and other organizations set up strategic collection points throughout the region hit by Katrina. Donations received in these sites were then sent to warehouses for classification and distribution. However, the volunteers and staff available at these staging areas were not sufficient in number to manage the influx of goods received (14, p. 328). In addition, there was a perceived lack of donations planning. A local respondent interviewed stated, "Another thing we need in our plan is donated goods. There needs to be a section within FEMA, or the state, or somebody besides VOAD in conjunction with VOAD that needs to be responsible for donated goods." Some organization representatives complained that communication with the government was inefficient and that they did not know what the priorities and urgent needs of the victims were, especially in rural areas. The interviews suggest that in addition to having inadequate facilities for storing donations, arranging for the transportation and movement of goods from warehouses to shelters and other distribution points was challenging. Furthermore, there was no clear plan for the distribution of donations. Some evacuees were sent from place to place in search of assistance, and when they eventually reached regional warehouses, the facility was not prepared to assist individuals.

As in other disasters, donations of low-priority goods hampered more important activities—the flow of clothing being the most problematic. Although the affected population did not need clothing as much as food, water, and ice during the first 2 weeks after the landfall, large quantities of clothing continued to arrive at shelters and staging areas. Clothing was not considered in the official plans for relief operations and no facilities were designated to distribute it. Incoming trucks loaded with clothing sometimes dropped their cargo at parking lots, where it had to be picked up and protected from the rain. Agencies improvised and set up tents to distribute lower-priority items such as clothing, medical kits, cleaning supplies, and diapers.

Procurement

Procurement delays may be the single most important factor explaining the slow flow of critical supplies after the initial response. The information gathered by the authors indicates that "delivery times were horrible. Small quantities were OK [however, delivery of] large quantities [was] very bad." The same respondent said that the delivery of large quantities took 2 to 6 weeks after requisition, while the delivery of medical supplies took 1 to 3 weeks because the general logistics staff were unfamiliar with the specific supplies and where best to acquire them. One generally positive strategy used during this

disaster sometimes generated delays. It is commonly understood that buying from local businesses is a good postdisaster practice because it feeds funds back into an economy that may be devastated. However, in this case, local suppliers were not always able to supply goods in the necessary quantities, which generated a delay as staff searched for goods available from local businesses.

To a great extent, the delay was also the result of the lack of proper purchase agreements with suppliers, a bureaucratic mind-set in the midst of an emergency, and lack of experienced personnel. For example, after an order for portable toilets had been fulfilled (after a delay of almost 2 weeks), the staff realized that the service agreements to remove the waste from the toilets and replenish the chemicals had not been in place. The procurement delays affecting critical supplies were the source of considerable frustration and anger among experienced responders. In the opinion of one official, "The key supplies are about 350. FEMA should have had all of them in place." Not having adequate purchase agreements led to unnecessary delays in the delivery of supplies.

Another set of procurement issues was related to the bureaucratic nature of the process. The "pull" system defined by the NRP for the provision of federal resources to local communities establishes a procurement process with five layers of jurisdiction (parishes are at the lower level and federal agencies are at the top). The process requires several time-consuming approval signatures and data-processing steps before any action, thus delaying the response (12, p. 52). Officials at all levels of the supply chain complained that paperwork and the centralized dependence on FEMA's logistics system severely hampered the immediate response. A volunteer for a nonprofit organization stated, "When I work under FEMA, it changes some of my rules." Even Louisiana's governor (12, p. 48) and FEMA's director (14, p. 326) said that bureaucracy and rigid processes limited their ability to adapt quickly to emerging needs. In some instances, the federal government had resources available that were not effectively deployed where required because the requests were being "coordinated" somewhere in the bureaucratic process (12, p. 70).

The bureaucratic logistics system also confused officials at various government levels, which sometimes had no clear understanding of the roles and interactions among local, state, and federal agencies, including the military. As one FEMA staff person indicated, "The military is great, but military and volunteer agencies don't interact very [well together]."

Limited Asset Visibility

Asset visibility was seriously obstructed at both ends of the supply chain (14, pp. 320–323). For some local governments, estimating the quantity and type of critical supplies needed was almost impossible due to the size of disaster and the limited resources available. At the other end, FEMA had difficulties in determining the supplies needed, the resources it had available, and the location of a resource at a given time. For example, reports suggest that FEMA ordered 211 million pounds of ice over about 1 week after Katrina, exceeding by far both the amount needed and the capacity of FEMA's distribution system (16). Not knowing what to do with the ice, truck drivers were repetitively asked to take their cargo from one place to the other in a frustrating journey that would last, in some cases, more than a week and would require traveling more than 4,100 mi. At the end, about 60% of the ice was deemed unnecessary and stored across the nation for future emergencies, even though 13% of the original orders were canceled (16).

Lack of asset visibility was a major problem. Since no real-time tracking technology like the Global Positioning System (GPS) was used, agencies had no way to track the movement of goods once trucks left their warehouses. There were no means of communication between truck drivers and their destinations. Basic data such as who was driving what truck and expected arrival times were unknown. Although traffic signs were set up to direct truck drivers and police escorts were provided in some cases, many drivers did not reach their destinations. Some truck drivers became lost, got rid of their loads at the first opportunity, or simply left the area. In other instances, truck drivers were instructed by local officials to change course and unload the cargo at a site different from the intended destination. Shippers were usually not informed of such events, and thus their records were never updated to reflect the changes. Of particular interest is the case of several truckloads of emergency supplies that, according to interviews conducted with state officials, were sent to the now infamous Superdome, where many stranded New Orleans residents had sought shelter from the storm. Although a number of officials confirmed sending the trucks, nobody knows what happened to the trucks, since there is no evidence they ever reached the intended destination.

SUGGESTIONS FOR IMPROVEMENT

The identification of the key issues affecting the emergency logistics after Katrina leads to the pressing question of what must be done to avoid a repetition of this logistical disaster. The issues identified in the previous section can be grouped into three broad categories: the magnitude of the disaster and its implications, institutional issues, and the (purely) logistical issues. The main focus of this section is on the second and third categories. In this section, the authors propose a basic set of suggestions.

Create a Comprehensive Emergency Logistics Training Program

After interviewing numerous responders at all levels of government, the authors are convinced that—with some notable exceptions—many of those who were involved in the logistical operations did not have the necessary training to do the job under such extreme circumstances. Despite its identification as an important consideration in the NRP, in practice, emergency logistics has not been considered an important function. A comprehensive training program in emergency logistics could go a long way toward providing emergency responders with the skills they need to handle critical supply chains. In addition to training, frequent exercises should be performed to familiarize responders with the conditions and requirements inherent in large emergencies. Such exercises must truly test the capabilities of those involved in the operations, not simply serve to legitimate organizations that are required to demonstrate that exercises have taken place.

Create a Robust National Emergency Logistics Network

Interoperability could be improved by mandating that the computer systems in use at the state and local levels be able to interface seamlessly with FEMA's. From a technological standpoint, there are few barriers to implementing this strategy. From an organizational standpoint, however, strategies must be developed to overcome financial issues associated with system upgrading and training and with ensur-

ing that such systems adequately meet local, state, and federal needs. Although developing robust communication infrastructure is a challenging endeavor because of the widespread damage expected from large disasters, emergency agencies could improve robustness by making arrangements for alternative backup systems.

Develop Regional Blanket Purchasing Agreements

The unacceptable procurement delays that plagued the Katrina response could have been limited if FEMA had previously set up suitable contracts with suppliers. Experience has shown that the bulk of the immediate resource requirements after an extreme event can be handled with a finite set of critical supplies, most likely numbering between 350 and 500 items. Defining this list of critical supplies could provide the basis for a set of regional blanket purchasing agreements (RBPAs), which, following competitive bidding at each of the federal regions, would ensure that the suppliers are able to deliver the critical supplies in short order. The RBPAs could have a cascading clause that stipulates purchasing at the local level up to the point at which local suppliers cannot meet the needs; at that point state suppliers would come into the picture, followed by regional and then national suppliers. As part of the proposed RBPAs, regional and national suppliers would be required to use commercial vehicles equipped with GPS tracking devices to ensure asset visibility at all steps of the supply chain.

Implement Measures to Increase Asset Visibility

Responders should be able to establish situational awareness of logistical resources even in the absence of network connectivity. Providing responders with a better idea about critical supplies at the various stages of the supply chains is tied to the RBPAs discussed above. This is because the RBPAs could provide a suitable framework to increase visibility by requiring that regional and national suppliers adhere to the use of a standard tracking technology (e.g., GPS) or to computer systems that could be tapped from FEMA's. The information available should not be limited to the location of vehicles. The use of technologies such as radio frequency identification devices would provide field commanders and state officials with basic information about the contents of vehicles and pallets. To support the movement of goods into the affected areas, information about the condition of the transportation network should be provided. This could be achieved by the development of a website that would provide shippers with real-time information about the best routes to get into and out of the affected areas and about the conditions of these routes.

Develop Regional Compacts for Prepositioning of Critical Supplies

While some prepositioning of supplies did take place before Katrina, it was far below what was needed. Although it is not likely that prepositioning can solve all the problems after a major disaster, because there will always be unanticipated needs, regional stockpiles of prepositioned critical supplies could go a long way toward meeting immediate needs. The federal government should take the initiative and arrange regional mutual aid compacts by which the states in a federal region agree to purchase a basic set of critical supplies that would be kept in storage at key locations. Should an INS take place,

these supplies would become the first wave of resources to reach the affected area. Supplies that at some point may reach their expiration dates could be rotated out of the safety stock and flow into other humanitarian uses in the local areas.

Implement Proactive Donation Coordination Plans

As discussed elsewhere in the paper, donations—particularly of non-priority items—can severely hamper the flow of critical supplies by distracting resources from critical tasks. Proper handling and coordination of donations require a comprehensive approach involving the media, the private sector, volunteer organizations, and emergency response agencies. Stakeholders should be aware of the key features of the supply chain system, what formal and informal efforts are under way, and where critical gaps between supply and demand are emerging. This requires improving the flow of information to the public. As observed in major disasters, the quality of public information may be increased by the rapid establishment of a multiagency, multilevel joint information center. The center should provide a consolidated source of critical information from a large number of organizations, to which the media can refer to inform the public in a timely and accurate manner.

CONCLUSIONS

This paper has attempted to put together a comprehensive and unbiased picture of the key issues that led to the logistical debacle during the Katrina emergency. On the basis of public records and interviews with individuals directly involved in the logistical response at all levels (local, state, federal, and volunteer organizations), the authors identified three broad categories of issues: (a) initial impact on the system (i.e., magnitude of the requirements and impacts on the communication system), (b) institutional (i.e., understaffing and lack of training and lack of integration between federal and state logistics systems), and (c) logistical (i.e., inefficiencies in prepositioning resources, lack of planning for the handling and distribution of donations, procurement, and limited asset visibility).

These findings suggest that agencies at all levels of government share the blame for the logistical debacle post-Katrina, though the amount of blame is bound to be the subject of debate for years to come. There was a bright spot, however, that is related to the job done by volunteers and volunteer organizations. Horrendous as it was, the Katrina disaster would have been much worse if not for the outstanding job done by volunteer organizations that sent experienced and motivated leaders into the field who exhibited great ingenuity, creativity, and leadership in the face of a disaster without parallel in the history of the United States. At several critical junctures in the crisis, nameless volunteers were the ones who saved the day.

On the basis of the analyses conducted, a number of actions are recommended: (a) creation of a comprehensive emergency logistics training program; (b) improvement of the robustness and interoperability of federal, state, and local computer systems; (c) development of RBPA's; (d) implementation of measures to increase asset visibility; (e) development of regional compacts for the prepositioning of critical supplies; and (f) implementation of proactive donation coordination plans. The research team is currently complementing the data collection efforts with additional interviews. In addition, the research team is developing integrated modeling approaches to char-

acterize the behavior of multiple supply chains during extreme events, aiming to increase the nation's capability to respond to such events.

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REFERENCES

1. NOAA's Top Global Weather, Water and Climate Events of the 20th Century. National Oceanic and Atmospheric Administration, U.S. Department of Commerce. earth.unh.edu/esci409/docs2006/NOAA%20Global%20Impacts.pdf. Accessed July 15, 2006.
2. Mileti, D. S. *Disaster by Design: A Reassessment of Natural Hazards in the United States*. Joseph Henry Press, Washington, D.C., 1999.
3. Beamon, B. Humanitarian Relief Chains: Issues and Challenges. Presented at 34th International Conference on Computers and Industrial Engineering, San Francisco, Calif., 2004.
4. Scanlon, J. *Convergence Revisited: A New Perspective on a Little-Studied Topic*. Institute of Behavioral Sciences, University of Colorado, Boulder, 1991.
5. Fritz, C., and J. H. Mathewson. *Convergence Behavior in Disasters: A Problem in Social Control*. National Research Council, Washington, D.C., 1957.
6. Kendra, J., and T. Wachtendorf. Reconsidering Convergence and Convergence Legitimacy in Response to the World Trade Center Disaster. In *Terrorism and Disaster: New Threats, New Ideas* (L. Clarke, ed.), Elsevier, New York, 2003, pp. 97–122.
7. Zakour, M., and D. F. Gillespie. Effects of Organizational Type and Localism on Volunteerism and Resource Sharing During Disasters. *Non-profit and Voluntary Sector Quarterly*, Vol. 27, No. 1, 1998, pp. 49–65.
8. Wenger, D. E., and T. F. James. The Convergence of Volunteers in a Consensus Crisis: The Case of the 1985 Mexico City Earthquake. In *Disasters, Collective Behavior, and Social Organization* (R. R. Dynes and K. J. Tierney, eds.), University of Delaware Press, Newark, 1994.
9. Neal, D. M. The Consequences of Excessive Unrequested Donations: The Case of Hurricane Andrew. *Disaster Management*, Vol. 6, No. 1, 1994, pp. 23–28.
10. *Logistics and Effective Delivery of Humanitarian Relief*. Fritz Institute, San Francisco, Calif., 2005.
11. Hurricane Katrina Service Assessment. National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 2006. www.weather.gov/om/assessments/pdfs/Katrina.pdf. Accessed July 28, 2006.
12. *The Federal Response to Hurricane Katrina: Lessons Learned*. Report to the President, Washington, D.C., Feb. 2006.
13. Filosa, G. Storm Victim's Body Is Found in Mid-City Home. *Times-Picayune*, May 28, 2006, Metro, p. 1.
14. *A Failure of Initiative: The Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina*. U.S. House of Representatives, 2006.
15. *A Performance Review of FEMA's Disaster Management Activities in Response to Hurricane Katrina*. Office of the Inspector General, Department of Homeland Security, 2006.
16. Shane, S., and E. Lipton. Ice Odyssey Teaches Wider Lesson. *Times Union*, Oct. 2, 2005, p. A15.