EFFECTS OF CATASTROPHIC EVENTS ON TRANSPORTATION SYSTEM MANAGEMENT AND OPERATIONS

Allan J. DeBlasio

U.S. Department of Transportation
John A. Volpe National
Transportation Systems Center
Cambridge, MA

Prepared for
Workshop on
Optimizing Resource Allocation for
Transportation Infrastructure Protection

University of Wisconsin-Madison

May 20, 2004

EFFECTS OF CATASTROPHIC EVENTS ON TRANSPORTATION SYSTEM MANAGEMENT AND OPERATIONS

To better understand how the surface transportation system is both affected and utilized in an emergency situation, the Federal Highway Administration (FHWA) Office of Operations and the U.S. Department of Transportation (U.S. DOT) Intelligent Transportation Systems (ITS) Joint Program Office commissioned a series of six case studies examining the effects of catastrophic events on transportation system management and operations:

1. Blackout, New York-New Jersey-Connecticut Metropolitan Area, August 14, 2003
2. Blackout, Great Lakes Region, August 14, 2003
3. Terrorist attack, New York City, September 11, 2001
4. Terrorist attack, Washington, D.C., September 11, 2001
5. Rail tunnel fire, Baltimore, Maryland, July 18, 2001
6. Earthquake, Northridge, California, January 18, 1994.

This report is a summary of the case studies completed by the U.S. DOT's John A. Volpe National Transportation Systems Center (Volpe Center) and Science Applications International Corporation (SAIC). It documents the actions taken by transportation agencies in response to catastrophic events in order to examine the impacts of different types of events on transportation system facilities and services. The event descriptions and the findings in this report are a result of the creation of a detailed chronology of events, a literature search, and interviews of key personnel involved in transportation operations decision-making for six events:

The intended audience for the case studies extends beyond the traditional transportation community. These works are intended to help various federal, state, regional, county, and municipal personnel at emergency response and management agencies, health and human services agencies, public works agencies, and public safety agencies better understand the ability of the transportation agencies to aid in the response and recovery from catastrophic events. Coordinated and advanced planning across agencies and jurisdictions can lead to better response in times of emergency.

The findings of the case studies were also used in a series of Transportation Response and Recovery Workshops that were developed by FHWA staff and held in major metropolitan areas around the country. The primary goal of the workshops is to bring together representatives of these various agencies to better understand the issues and understand the importance of planning and coordination before, during, and after events. These case studies help document the value in planning, coordinating, and investing in infrastructure and technology that can help in times of crisis.

This document has two main sections. The first section provides an overview of each of the six case studies. The second section discusses findings that cut across the six case studies.

1.0 Summary of the Six Catastrophic Events

Each of the events resulted in substantial, immediate, and adverse impacts on the transportation system, and each has had a varying degree of influence on the longer-term operation of transportation facilities and services in its respective region.

1.1 Blackout: New York-New Jersey-Connecticut Metropolitan Area

On August 14, 2003, at approximately 4:11 p.m., most of the New York City area lost all electrical power. Because they initially lacked information on the cause of the power outage, transportation managers responded at first as if the blackout may have been a terrorist attack. After learning more about the cause of the blackout and its extent, managers shifted their focus from security to safety, and then to the restoration of mobility.

Throughout the region, all subway systems stopped operating stranding 413 trains and 400,000 riders in the New York City Transit (NYC Transit) subway system and 19 Port Authority Trans-Hudson (PATH) line trains of which 16 were in tunnels. Within three hours after the start of the blackout, both systems were successfully evacuated with only three reported minor injuries.

All of New York City's 11,600 signalized intersections lost power causing the traffic signals to stop working. This led to massive traffic jams. Uniformed police officers assigned to the Traffic Division were unable to direct traffic because they were called to respond to emergency situations such as freeing people from stuck elevators. Pedestrians and stranded motorists were often seen directing traffic at major intersections.

Operators of the bridges and tunnels leading from Manhattan implemented certain restrictions. The Lincoln Tunnel and the Brooklyn, Williamsburg, and Manhattan Bridges were closed to Manhattan-bound traffic. The Queens Midtown and the Brooklyn Battery tunnels were closed except for emergency vehicles. The toll roads in and around New York City continued operating. Managers of these facilities, except for the New York Thruway Authority, suspended tolls to accommodate the abnormal flow of traffic. With a few exceptions, most ITS field equipment lost power and could not be used.

The Port Authority Bus Terminal (PABT) in Midtown Manhattan was evacuated, forcing commuters on to the streets around the terminal. New Jersey Transit (NJ Transit) staff started a load-and-go operation, busing commuters from the PABT to the Meadowlands in New Jersey, and then implementing bus routes to get these customers to their final destinations. NJ

Transit staff did the same for travelers arriving by ferry at the New Jersey docks as agency staff bused them to the Meadowlands to transfer to other buses. NJ Transit staff also started a bus bridge the paralleled the powerless Hoboken light rail line.

Power was completely restored to New York City by 9:00 p.m. Friday, August 15. The NYC Transit subway system resumed partial customer service during the early morning of Saturday, August 15 with full service starting at 6:00 a.m. on Saturday. By Sunday night, August 17, NYC DOT crews had completed the task of inspecting all of its traffic signals and indicated that the signals were fully functional.

1.2 Blackout: Great Lakes Region

Similarly, power in the Great Lakes regions failed around 4:10 p.m. on August 14, 2003. The Greater Cleveland Regional Transportation Authority (RTA) rail system failed and had to be evacuated. Traffic lights in Detroit and Cleveland and the surrounding communities also went dark, resulting in severe traffic congestion and traffic being directed by citizens. Traffic moving from Detroit to Ontario, Canada, was slowed because of a power loss at Canadian customs, and shipment processing had to be performed manually. Except for the Ohio Turnpike, ITS field equipment did not have backup power supplies and, therefore, became inoperable. ITS at the Suburban Mobility Authority for Regional Transportation (SMART), an automatic vehicle location (AVL) system, a geographic information system, and a Website, also continued to operate with backup power.

By 4:10 a.m. Friday, August 15, power was slowly being restored to the Cleveland area and by early evening, Saturday, full power was returned to the Cleveland area. Similarly, power was restored to the Detroit area by Saturday evening.

1.3 Terrorist Attack: New York City

On September 11, 2001, New York City was the target of the largest terrorist attack in the history of the nation. Both World Trade Center towers were hit and destroyed by hijacked passenger jets. These attacks occurred during the morning rush hour and the transportation network was immediately and dramatically affected.

NYC Transit and PATH stations and rail lines in Lower Manhattan were destroyed during the collapse of the towers. Transportation officials were immediately faced with the need to make critical decisions to protect the safety of residents and workers and the critical transportation infrastructure. This task was complicated by the lack of clear information about the scope of the damage to the system and the uncertainty of future attacks.

Within minutes of the first attack, transportation officials were confronted with the need to respond on three critical levels. First, the agencies began the process of closing all of the bridge and tunnel crossings into Manhattan to non-emergency vehicles, suspended subway service to Lower Manhattan, and closed the three international airports in the metropolitan area. Second, officials were confronted with the daunting task of evacuating the 1.2 million workers and residents of Lower Manhattan. Third, transportation agencies were mobilizing workers and resources to aid in the response and recovery effort at the World Trade Center site.

1.4 Terrorist Attack: Washington, D.C.

A third hijacked passenger jet also attacked the Pentagon, located in Arlington, Virginia, on the morning of September 11, 2001. This event required a coordinated response from multiple agencies within multiple jurisdictions. Jurisdictions involved included those from the states of Virginia and Maryland, the District of Columbia, local and county governments, the United States Department of Defense, and other numerous federal agencies. As with New York City, the lack of clear information about subsequent attacks led to a series of independent public and private decisions to evacuate the city during the end of the morning rush hour.

The transportation agencies had to respond to the attack and subsequent partial evacuation by closing certain key transportation facilities near the Pentagon and other strategic locations in the nation's capital, redirecting transit assets, and coordinating these closing and changes with other agencies. This was all happening during a time when the voice communications networks were overwhelmed with demand and accurate information on closings and redeployments was scarce.

1.5 Rail Tunnel Fire: Baltimore, Maryland

On the afternoon of July 18, 2001, a fire broke out inside the 1.7-mile long freight rail tunnel running under Howard Street. A 60-car CSX freight train carrying various potentially hazardous materials had derailed inside the tunnel and some of the rail cars were on fire. Smoke was billowing out of the train portals as local fire, police, and emergency response personnel reported to the scene. Howard Street is a major arterial that runs through the heart of Baltimore's business and cultural districts. A light rail and commuter rail line operated along the Howard Street right-of-way above the rail tunnel.

Officials were confronted with major disruption to the roadway, transit, and freight networks in the central city just as the afternoon rush hour was about to begin. City officials were faced with multiple challenges once the fire was detected. First, there was the need to determine the exact location of the fire in the tunnel. Second, it was crucial to determine the potential environmental impact from the cargo on the 60 rail cars. Third, a major water main located above the tunnel had ruptured and was flooding sections of the tunnel. Fourth, they needed to quickly determine to what extend an evacuation of the surrounding area would need to occur.

Coordination issues were complicated because of the numerous parts of the infrastructure involved, the uncertainty of the extent of threat, and the freight rail line is owned by a private company, CSX. Also, different Baltimore city agencies maintain the roadway and the water infrastructure, and the Maryland Transit Administration (MTA) operates the light rail and commuter rail lines. When the fire department initially responded, its primary focus was on fire suppression. This focus later shifted to environmental safety once it was realized that hazardous materials might be involved.

1.6 Earthquake: Northridge, California

On January 17, 1994, a 6.8 magnitude earthquake shook the Los Angeles region. The actual earthquake only lasted about 1 minute, but caused an estimated $25 billion in property damage. In addition to the numerous disruptions of local roads, sections of four major freeways were severely damaged.

These damaged sections of freeway served an average of 1 million travelers on a daily basis. The local and state transportation officials were confronted with a two-fold problem. The first was to inspect the vast infrastructure network for damage, and the second was to begin and complete the reconstruction effort as quickly as possible.

The Southern California region had dealt with numerous catastrophic events over the past several decades. This included previous earthquakes, mudslides, forest fires, and civil unrest. Because of this history, the region had in place a coordinated strategy for response to and recovery from disasters. The California Department of Transportation (Caltrans) immediately began the inspection of its infrastructure and had agreements with private contractors to begin the removal of debris by the evening of the first day.

Detours around the affected areas were in place by the first afternoon. These detours would undergo constant refinement over the next several months. Through innovative design and construction methods, the state was able to reconstruct and reopen some of the damaged sections of the freeway within three months. All of the sections were reopened within 10 months of the earthquake.

2.0 Summary of the Findings

Each of the events presented transportation officials, managers, and staff with a different set of challenges in the response and recovery effort. There were several key themes that cut across the four events. These themes are divided into two categories: Guiding Priorities and Plan of Action.

2.1 Guiding Priorities

The initial guiding priority in every emergency is the protection of life. After a major catastrophe, transportation officials must begin immediately to work with emergency responders, to implement evacuation plans, and to institute recovery procedures. In each of these case studies, officials were charged with making decisions without full knowledge of the rapidly changing existing conditions and uncertainty of what future events might occur to change the situation. Because of this, safety and security took priority over mobility in all the events that were reviewed.

Actions Taken
• Protect lives • Provide access to emergency responders • Ensure security • Ensure safety • Reestablish mobility

As time passed and more information was available, officials began to restore mobility. This restoration of mobility varied with each of the events. It depended on the severity of the event, in terms of devastation and geographic area affected, and the effect on the transportation system. Immediately following an incident, managers had to weigh the advantages of limiting certain aspects of the transportation system to emergency personnel and vehicles against opening the facilities to general traffic to support the evacuation of the affected area.

Mobility in the areas affected by the blackout was gradually restored as power was restored. Most traffic signal systems, ITS equipment, and electrified transit systems were back in operation within two days. Similarly, mobility was restored to the Washington and Baltimore areas within days because the event was confined to a small area. Because of the physical damage in New York, after the terrorist attack, and Los Angeles, however, it was months before key pieces of the transportation infrastructure could be reopened to the general traveling public at normal levels.

2.2 Plan of Action

In order to respond to a catastrophic event, agencies need to have a plan of action in place to handle emergency situations and to begin the process of restoring mobility. This plan of action includes both planning and investing in infrastructure and personnel. The plan of action is organized around six categories:

1. Advanced preparation and planning
2. Operating decisions
3. Institutional coordination
4. Role of advanced technology
5. Technical communications
6. System redundancy and resiliency

2.2.1 Advance Preparations and Planning

The need for advance preparation and planning by agencies is crucial in dealing with a range of mishaps and disasters. Several key themes emerged from the six case studies.

Actions Taken
• Learned from previous events and adapted plans to incorporate findings • Developed and drilled emergency response plans • Established emergency operations centers • Adopted incident command systems (ICS) • Developed cooperative agreements among agencies • Installed seamless backup power supplies • Initiated emergency response procedures within minutes of an event

First, agency personnel need to learn from previous events and incorporate that learning into an agency's response plans. Previous events, especially those of September 11, have served as a wake up call to officials in cities and towns across the country about the need to prepare for the unexpected. Second, there is a need to develop emergency response plans and train agency staff at all levels to make good and timely decisions, often without complete knowledge of all the mitigating circumstances.

Third, by learning from other events, agency officials have created or upgraded emergency operations centers. In some instances, such as NJ Transit and NYC Transit, managers have also built mobile centers to serve as a backup. Managers at other agencies have also identified facilities that could be used as a backup in case their primary center cannot function properly.

Fourth, officials in many agencies have trained their employees in incident command systems (ICS). The ICS was developed in California in response to the rash of forest fires in the 1970s, to overcome coordination problems among multiple agencies. Transportation agency managers acknowledge that a response to an emergency may involve several divisions within an agency or many representatives from several agencies and, over time, have looked to the ICS to help coordinate response activities. Managers recognize that a well-understood chain of command is essential to an efficient and effective response.

Fifth, when planning for a major incident, agency managers must identify what resources they have or can obtain and those that they cannot. Often, financial constraints prohibit agency staff from procuring all of the resources they identified. In these circumstances, agency officials must work together to identify which agencies have what type of resources and the circumstances in which these resources can be shared. Transportation officials stressed developing memoranda of understanding or other written instruments to document such agreements.

Sixth, learning from past experiences has caused transportation officials to investigate their need for backup power sources. The blackout, in particular, has brought this need to the forefront. Many managers have faced blackout in the past, but these were local in scope and short in duration. Although many facilities had varying types of redundant power sources, agency managers never imagined that they would lose power from multiple sources, in one case four different sources. Staffs at most toll authorities were able to continue operations during the blackout, because their management had previously placed a high priority on continuing service during a power outage and invested heavily in sources of backup power.

Staffs in those agencies that have prepared for serious events knew what to do shortly after the incident started. During some of the events studied, management of several agencies went directly to their emergency operations centers without being notified when they first heard of the event. This enabled them to quickly assess the situation and start remedial action. Actions taken by two subway crews within minutes of the attack on September 11 were cited as examples of staff knowing their agencies' plans and being given the authority to act independently, if needed. They were credited with saving hundreds of lives.

2.2.2 Operating Decisions

Because emergencies are unpredictable and come in many different forms, agency managers cannot plan for all contingencies and may have to make a number of operating decisions during a catastrophic event.

Actions Taken
• Set priorities as quickly and accurately as possible based on available information • Sustained operations according to established continuity of operations procedures • Worked with first responders to provide necessary help • Empowered field staff to make field decisions • Implemented established procedures for evacuations when necessary • Shared resources with other agencies

Very often, they must make field decisions without the benefit of full knowledge of the event. During the six events reviewed, managers and staff members set their priorities as quickly and accurately as they could and implemented activities that reflected these priorities.

Many agencies had established continuity of operations plans. Management at several of the toll authorities had previously determined that their facilities would continue to operate during most emergencies and had acquired the resources to do so. Continuity of operations plans may also include closing a facility under certain circumstances. For example, the Detroit–Windsor Tunnel has never previously lost all four of its independent power feeds simultaneously. Following their operations plans, tunnel staff made the swift decision to close and evacuate the tunnel within 15 minutes of losing power.

Transportation officials noted that at the start of each event supporting emergency responders was their highest priority. In particular, in the two New York City events, managers made decisions to restrict traffic on bridges and in tunnels leading into Manhattan to allow access to emergency vehicles. Similarly, decisions restricting the use of roadways were made in Washington, D.C., on September 11.

Many transportation officials stressed the need to empower field staff to make decisions when required. Because of the potential loss of communications between managers and field staff, it is imperative to address who is authorized to make what kinds of decisions, under what circumstances these decisions can be made, and how decisions should be communicated. Interviewees from New York City reported that on September 11, it was helpful for field staff to quickly make choices on their own in the absence of communications from headquarters personnel. Also early in the blackout, many decisions concerning re-routing NYC Transit buses were handled by local division supervisors until communications was restored with the main office.

Emergency plans for many agencies included procedures to evacuate the agency facilities. Following their evacuation plans, managers and crews of the NYC Transit subway system successfully evacuated 400,000 stranded passengers on the day of the blackout. Similarly, managers and crews of PATH and the Greater Cleveland RTA light rail system safely evacuated their patrons.

Several interviewees remarked that emergency equipment can be costly to purchase and store, and agencies cannot always predict what sorts of equipment they will need during an emergency. Managers emphasized the need to work with other agencies to promote the sharing of resources.

2.2.3 Institutional Coordination

In most catastrophic events, staffs in different divisions within an agency and representatives from a multitude of federal, state, regional, and local jurisdictions must be able to coordinate their efforts to respond effectively.

Most of the interviewees stressed that relationships must be established during the routine day-to-day activities of an agency and then build on these relationships during an emergency. As one official in New York City remarked, he and his staff view the management of each daily commute as an event that relies on the coordination of officials from transportation agencies, fire, police, and the news media.

Actions Taken
• Cultivated relationships during normal times to ease cooperation during an event • Linked the various arms of an organization for better internal coordination • Installed dedicated voice or data links to relevant agencies and organizations • Practiced an incident command system (ICS) • Established mutual aid agreements • Worked closely with countywide and statewide emergency operations centers • Provided information to the media as quickly as possible • After the event, collectively reviewed performance and cooperation

Staffs in agencies that have many operating entities or operate in multiple geographic locations face internal coordination challenges. Representatives from these agencies worked together to develop agency emergency response plans to ensure the roles and responsibilities of the various divisions are known. Managers at several agencies have adopted the ICS to facilitate their responses to an incident. Also, managers have linked their different divisions electronically. For example, the control centers for NJ Transit heavy rail, bus, and light rail are tied together through a telephone center.

Similarly in some areas, managers from several agencies came together to develop a regional ICS. They have also use electronics to coordinate response activities. Several major transportation agencies within the New York City area have been linked by dedicated telephone lines since September 11, 2001. Some transit agencies are also linked by dedicated telephone lines to their contract carriers.

As previously mentioned, interviewees asserted that no one agency can acquire and maintain all the equipment that is needed in an emergency. They stressed that they relied on mutual aid pacts to help them overcome an incident. This helps to reduce the need for costly expenditures and inefficient searches for equipment at the heights of crises. Aid could also come from the private sector. For example, through a memorandum of understanding between NJ Transit and private carriers, private fleets were available to assist in the movement of stranded commuters on the day of the blackout.

Many state and local governments set up emergency operations centers (EOCs) to coordinate a multi-agency response to a major incident. Managers of transportation agencies emphasized that close relationships must also be established with EOC staff. During the blackout, EOCs were opened in the states of New York and New Jersey and in the cities of New York and Cleveland. Interviewees noted that their interaction with EOC staffs provided positive results. For instance, NJ Transit staff was able to acquire portable lighting and water and food bars for stranded commuters through the New Jersey Office of Emergency Management.

Some transportation managers found communicating with the media and the public very challenging during an emergency. They stated that information must be given to the media as quickly as possible to ensure that rumors do not spread and to assure the public that facilities are safe and to explain the reasons for closing certain facilities. On September 11, inaccurate information was disseminated that the Washington, D.C., Metrorail was closed, which resulted in people who were trying to get home walking on the streets and adding to the congestion rather than taking the subway. During the blackout, personnel at the Detroit-Windsor Tunnel placed a high emphasis on providing reliable information. At times they physically traveled to radio stations because the stations lost their telephone service.

Following any kind of emergency, it is vital that the managers and staffs at the partner agencies who worked together review and evaluate their performance during the emergency. Two reviews conducted after the blackout serve as examples. First, staff members from the Ambassador Bridge, the Detroit–Canada Tunnel Corporation, U.S. and Canada Customs, local law enforcement agencies, and other entities participated in a Detroit–Windsor regional transportation debriefing to discuss their performance during the blackout. Participants discussed issues such as backup power generation, coordinated radio communications, EOCs, border operations, and communications with the public.

Second, a coalition of transportation and emergency response agencies formed the Trans-Hudson Emergency Transportation Task Force. This task force focused on issues relating to moving people from New York City to New Jersey.

2.2.4 Role of Advanced Technologies

In all six case studies, interviewees discussed the benefits of advanced technologies, especially intelligent transportation systems (ITS). They said these technologies could (1) provide information on which decisions regarding the availability of facilities can be made, (2) serve as a mechanism by which information can be disseminated to other public and private organizations, and (3) be used to inform the public about the status of the transportation system.

Actions Taken
• Utilized multiple forms of ITS to broadcast information to travelers • Used CCTV images to assess traffic conditions and modify operations accordingly • Used real-time ITS traffic data to design detours and facilitate evacuation • Utilized ITS to alert motorists outside of the affected area of problems ahead • Utilized ITS to link TMCs to share travel conditions information among centers

Agency managers had access to multiple types of ITS. Many operated traffic or transit management or operations centers, and within these centers, they used advanced traveler information systems to release information. In the field, they had access to variable messages signs (VMS) and highway advisory radio (HAR) systems. On September 11, for example, two minutes after the decision was made to close the bridge, VMS alerted motorists ten miles away from the George Washington Bridge that the bridge was closed.

Agency managers also used ITS equipment to collect data to help in making operating decisions. They used closed circuit television (CCTV) cameras, vehicle detection devices, and AVL systems to monitor traffic flows and prohibit or restrict traffic on certain facilities. After September 11, traffic along key sections of the roadway system, including the bridges and tunnels into Manhattan, was measured. That information was then used to help determine changes in the duration of the single-occupancy vehicle ban implemented for the lower Manhattan crossings in the fall of 2001.

In addition, ITS equipment was used by agencies not affected by the event. On September 11 and during the blackout, VMS and HAR in bordering states broadcasted messages alerting motorists to avoid New York City. By receiving messages as far south as Maryland, motorists were able to use alternate routes or cancel non-essential trips toward the affected areas. Giving ample warning of an event ahead is especially useful to truckers, who are usually more restricted in the alternative routes they can take and under just-in-time delivery deadlines. For the Baltimore rail tunnel fire, staff at Maryland's Coordinated Highways Action Response Team (CHART) traffic management center (TMC) were able to post messages that provided information to travelers on the closing of roadways into Baltimore.

ITS can also serve as an important tool to link TMCs within a region. For instance, the Interagency Remote Video Network (IRVN) in the New York City area connects 13 TMCs and facilitates the sharing video feeds of 13 transportation agencies. During major events, this network allowed staffs of other agencies to better understand what was happening outside of their purview that might have a significant impact on their operations.

The availability of ITS products and services, however, varied during the six emergencies. As staffs at many agencies discovered during the 2003 blackout, advanced technology is vulnerable to the loss of power at any point along the communication network, from equipment in the field to the control centers. One official in the Great Lakes region commented that without power, ITS data "go right in the wastebasket, during a time when you could ultimately use it the most." As agencies incorporate ITS equipment into their daily operations activities, it is important to identify those parts of the ITS network that should be capable of operating during a blackout or other emergency situation, and allocate funds to maintain backup power in those parts of the system.

2.2.5 Technical Communications

In the six events studied, the loss of communications or inability to communicate successfully was always cited as a major obstacle to a quick and efficient response. In the incidents that involved a loss of power, transportation personnel (1) thought that they had more redundancy in their communications systems than they did, (2) did not fully understanding the frailty of their technology, and (3) thought they had better emergency backup power capabilities than they in fact had.

Actions Taken
• Utilized multiple communications technologies to ensure at least one form of communications would be working • Adopted new forms of communications as new technology was developed and refined • Sometimes relied on old technology, such as using a landline and a holdover dialup modem, when newer technology failed • Executed established non-communications plans when necessary • Utilized government-sponsored priority communications systems such as GETS and WPS

This loss of communications always occurs at a time when information is needed to transmit instructions to field staff, coordinate activities with other agencies, and accurately inform the public of the event.

The six reviews showed that the more communications options that are available to an agency, the more likely that agency will continue to operate. As one interviewee declared, "Nothing worked all the time." During each event some technologies continued to operate while others failed, but the technologies that continued to work varied from event to event. For example, during the August 14 blackout, the plain old telephone system (POTS) proved to be the most reliable technology. In contrast, after the Northridge earthquake, the telephone system failed because of fires at switching stations, and switching centers shut down because of the large number of receivers knocked off the hook during the earthquake and aftershocks.

Similarly, the availability of cellular telephone systems varied not only from event to event but also within an event. At first, transportation staffs in D.C. were able to use the POTS until the circuits on the East Coast jammed. Then they had to switch to cellular phones and other devices. During the blackout, the reverse happened. In the early stages of the event, staffs were able to use cellular telephones. After a while, however, the battery backup supplies became exhausted and cell phone towers failed to operate.

In preparing for catastrophic events and other emergencies, transportation agency managers adopted a variety of new technologies. These include global satellite telephones, instant messaging programs, and walkie-talkies incorporated into cellular telephones. Two transit agencies had mobile communications centers - buses equipped with satellite and computer technology,

Interviewees also stressed the importance of older technologies. Agency representatives used a combination of facsimile machines, pagers, 800 numbers and conference call lines, older radio systems, and previously installed dedicated landlines to communicate within and among agencies. The NYC Transit subway staff relied on battery powered handheld radios to successfully evacuate their system during the blackout. Whereas, both TRANSCOM and NJ Transit management have established 800 numbers into which staffs from the various agencies can call and conduct conference calls. Furthermore, TRANSCOM management had a contract with a firm in Florida to provide a facsimile service. Staff provided information to this "fax vendor," which in turn sent facsimiles to the TRANSCOM member agencies and other parties.

Because of previous incidents, management at several agencies had prepared and drilled their personnel specifically for the failure of communications equipment. These managers have established "non-communications" plans so that employees know what actions to perform in an emergency when their standard communications equipment fails and they cannot contact their supervisors. NJ Transit management has designed emergency bus operations that its drivers know to implement in the event of an emergency. Similarly during the daily roll call, NYPD Traffic Division supervisors provide their officers designated locations to cover in the event of an emergency.

Transportation agency officials have also been requesting and being given access to the Government Emergency Telecommunications Service (GETS) and the Wireless Priority Service (WPS). These two services are government sponsored priority communications systems that provide pre-approved users with priority routing of landline (GETS) and wireless (WPS) calls during times of emergency and crisis, even during periods of peak demand. In most cases, the use of these services during emergency situations, which typically generate significant demand for telephone services and may overwhelm the capacity available within the national telecommunications network, facilitate communications for the subscribing agencies.

2.2.6 System Redundancy and Resiliency

The concept of redundancy - having systems in reserve in case primary systems fail - is a common thread running through all of the previous findings. When planning for emergencies, managers must identify the key functions of their agency. Then they must ensure that these functions can be continued during an incident by investing in the required resources. Some large-scale emergencies, such as the August 14 blackout however, may exceed the amount of available redundancy. Therefore when planning for redundancy, managers must assume the most likely types of potential emergencies and take into consideration financial and other constraints.

Furthermore, redundancy must be established within agency personnel. Staff members must be trained to take over the role of a colleague if that coworker is not available. They also must be trained to make decisions when they cannot communicate with their supervisors.

Actions Taken
• Expended resources to provide for redundancy in personnel and infrastructure • Bolstered alternative transportation services to help replace unavailable modes, such as providing extra buses, trains, or boats • Used redundant traffic corridors to establish detour routes to circumvent unavailable infrastructure • Trained personnel to be able to fill in for key players who may be unavailable • Trained and empowered the decentralized field staff to make independent decisions • Utilized multiple technologies to communicate with staff, other agencies, and the public • Installed backup power supplies for critical equipment and facilities • Built mobile command centers to supplement fixed control centers • Inventoried existing supplies and equipment • Established outside sources for additional supplies on short notice

Transportation officials must be aware of the redundancy in their transportation systems and take advantage of it during major incidents. For example in the two events in the New York City area, ferries were used to bring commuters from Manhattan to New Jersey when the major roadway and transit river crossings were unavailable. Also in most of the events, buses were used to replace or supplement service when other modes were not functioning.

As witnessed in the six case studies, no one form of communications continued to function in every event. Organizations reported using a little of everything: telephones, facsimile machines, electronic mail, cellular telephones, pagers, text messaging, two-way and short wave radios, and face-to-face contact, when all else failed.

Redundancy is also needed for infrastructure components. Most importantly, a backup power source is necessary for the equipment required to continue operations. The management of each of the agencies involved in the case studies viewed redundancy in terms of what their agency's functions were, what functions they wanted to continue to operate, and what equipment was needed for those functions. As previously mentioned, managers at several toll authorities invested in backup technology and equipment to ensure that their toll collection facilities continue to operate during times of emergencies. On the other hand, managers for the Port Authority Bus Terminal had previously decided that the terminal would be evacuated during any major incident and provided only enough backup power to accomplish that task.

Sometimes duplicate equipment is needed to take over the functions of an agency's main control center. Some agency's have or were in the process of developing centers that were situated a distance from their primary site. Management at NJ Transit and NYC Transit went one step further and decided that their alternate centers would be mobile.

Another key aspect to a successful response is the knowledge of the resources that are available. Agency managers stressed the need to know not only what equipment and supplies were on hand at the agency, but also what equipment and supplies could be obtained from other entities.

As managers and staffs of transportation agencies experience major incidents, they learn more about the consequences of such events. They now understand and appreciate the value of proper preparation. Through advance planning, staff are trained to make decisions when the normal organizational structure is disrupted. Furthermore, managers and staffs are encouraged to work with personnel from other transportation agencies and from non-transportation organizations as well. In addition, they also have come to understand the importance of their communication systems and other technologies on which they rely in their day-to-day activities and may take for granted. Transportation personnel now try to ensure that their systems are resilient and have backups when needed.

3.0 Additional Information

The Baltimore rail tunnel fire case study, the Northridge earthquake case study, and a crosscutting report covering the first four case studies can be found in the FHWA ITS Electronic Data Library (EDL) site at http://www.its.dot.gov/itsweb/welcome.htm. The two case studies on the blackout and a comparative analysis of the six case studies will be available in the EDL in June 2004. Additional information on the New York City and Washington, D.C., case studies can be obtained by contacting Vincent Pearce, FHWA Office of Transportation Operations, at vince.pearce@fhwa.dot.gov.