Commission Briefing Paper 4E-02

Evaluation of the Systems' Available Redundancy to Compensate for Loss of Transportation Assets Resulting from Natural Disasters or Terrorist Attacks

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Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 1909 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)**.** The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909 and will serve as background material in developing the analyses to be presented in the final report of the Commission. For the purposes of this paper, it is recognized that damage to the transportation infrastructure may be caused by natural or man-made disasters or through malevolent acts, which include special security and law enforcement considerations.

Transportation system redundancy is the resiliency that enables the system to compensate for losses and allows the system to function even when infrastructure is damaged or destroyed. For a transportation system at risk of disruption, availability of excess capacity provides redundancy which is needed not only for infrastructure and evacuation but also for the national transportation network. The National Cooperative Highway Research Program (NCHRP) Report 525: *Surface Transportation Security Volume 3* notes that "Manhattan has a highly redundant and densely interconnected roadway and public transportation infrastructure elements, including local streets, major arteries, subway and surface rail, bus service, commuter rail, Amtrak, ferries, and pedestrian pathways" which were critical to movement when tunnels and bridges were closed as a result of the 9/11 attacks. Redundancy can be a useful investment for normal operations as well as for responding to disasters.

Redundancy among transportation modes is discussed separately in Commission Briefing Paper 4E-03, *Evaluation of the Potential Use of All Modes in Evacuations During Times of Emergencies*. This paper recognizes the importance of multiple transportation modes but stresses primarily the role of other elements in achieving redundancy. It provides information on the transportation system's ability to support local, State, Regional or Federal authorities in planning for and executing safe evacuations during disasters or emergencies. It notes that implementation of safe and effective evacuations triggered by either manmade (e.g., hazardous materials incidents, transportation accidents or malevolent acts) or natural disasters (e.g., earthquakes, hurricanes, tsunamis, floods) depends upon local knowledge of the capabilities and availability of both public and private response and recovery resources.

Background and Key Findings
Evacuation operations are conducted under the authority of, and based on decisions by, local and State authorities. Evacuations may involve anywhere from tens of people to hundreds of thousands. Regardless of the numbers, in each and every instance the transportation network plays a key role in evacuating people out of harm's way. State and local transportation officials can maximize the use of the transportation network for their communities, States or regions through redundancy. Over the past two decades, the transportation community's ability to manage and operate the transportation network has improved considerably. Recognizing the unique challenges posed by the disaster environment on mobility and the safe and secure movement of people and goods into and away from the impacted area, there are local, State and Federal efforts to improve evacuation planning and implementation by bringing to the emergency management community new ways of better utilizing the transportation network before and during evacuations.

The availability of multiple modes is a fundamental element in transportation redundancy. However the roles of coordination, communications and technology systems, network connectivity, other infrastructure, and personnel are also critical to a transportation system's ability to compensate for loss of assets from a disaster. Redundancy can be created through the sharing of facilities, employees cross-trained in operating other modes, and additional or diverse equipment. Systems in place for operational purposes such as ITS can provide useful data for evacuation and disaster response. To be effective, redundancy must not only be available but used wisely by those who have the knowledge and training to take advantage of its benefits. Key findings include the following:

- The redundancy of the entire transportation system must be considered, with backup communications, routes, and information (including command, control, and data sources). Redundancy is critical for ensuring successful evacuations and other disaster response and also benefits the entire transportation network.
- Redundancy is largely provided by alternate transportation modes, and redundancy works best when modes are integrated. In the future, more modes will be integrated, and the health and vitality of each will depend on the others.
- Transportation chokepoints (i.e., bottlenecks due to geography such as a tunnel under a river or a road traversing a canyon) represent vulnerabilities where redundancy is particularly critical. Any route asset that is both concentrated and fixed can be affected by a disaster more than a mobile asset. Transportation and infrastructure itself (such as a multi-modal node or power supply) may be either the target of an attack or directly affected by the attack, in which case a key resource needed to carry out evacuation becomes unavailable.
- System redundancy, along with response and recovery measures, may be a better approach to terrorist events and acts of extreme violence than the development of prevention systems.
- During disaster response there is great need for accurate information in a dynamically changing environment. Cyberterrorism may take the form of a primary attack on communications or as part of a secondary attack designed to compromise response, which in either case would lead to inaccurate travel information.
- Transportation system rights-of-way are often used for placement of utility and fiber optic cables in tunnels and bridges. However, that convenience can be a liability

when that same infrastructure is damaged and redundancy is subsequently degraded due to loss of the Internet and other communications.

- Intelligent Transportation Systems (ITS), which are designed for operational use, can help provide redundancy during disaster response. Transportation/Traffic Management Centers (TMCs), Emergency Operations Centers (EOCs), and Incident Command Systems (ICSs) can also help optimize redundant resources through information sharing.

Threats to Transportation from Disasters and Terrorist Attacks

The 511 Deployment Commission's *Deployment Assistance Report #3: 511 and Homeland Security* notes that while a homeland security emergency has many parallels to a major incident in terms of detection, response, and recovery, there are notable differences. There is potential for large numbers of people to be the target of an attack or impacted by its immediate aftermath. Transportation and infrastructure itself may be the target of an attack or indirectly impacted, including power supplies. An attack could occur at any time, with or without warning, when available response resources are insufficient. An attack outside the knowledge and experience of transportation operations staff could delay an accurate assessment of need and appropriate response. An attack could even be designed to create confusion and lure emergency responders and civilians into a "trap."

All of these features highlight the need for accurate information in a dynamically changing environment and thus the need for communications redundancy. While rare, terrorism is now in the Nation's consciousness and is more of a concern since 9/11. Also, it necessarily involves Federal responders from both the consequence management and crisis management sides; for example, the FBI, ATF and Secret Service work alongside DHS/FEMA, USDOT, GSA and others. Internationally, highway infrastructure—especially mass transit with the potential for mass casualties—has been the most frequently targeted transportation mode.

Chokepoints and Infrastructure Vulnerabilities

Emergency response can be hindered by degradation of the transportation system. This could be due to a higher demand for an artery than usual, or due to debris resulting from pre- or post-incident impacts such as downed trees and utility poles or asphalt damage. Regardless of the trigger, chokepoints are the locations most susceptible to this degradation. Chokepoints can be due to natural features but more commonly include infrastructure such as the 600,000 bridges, 337 highway tunnels, and 211 transit tunnels interspersed across the 3.9 million miles of the national roadway system. Every major metropolitan area typically has bridges, tunnels, interchanges, and intermodal facilities.

Chokepoints are logical targets for malevolent acts, yet these same assets have value in emergency response. Certain transportation assets such as elevated lines or light rail cannot be moved, thus they are less able to be redeployed around a damaged area. To reach economies of scale, much of transportation infrastructure is concentrated in more profitable high-density corridors. Passenger airlines and, to some extent, railroads and the shipping industry use a "hub and spoke" approach that consolidates traffic at critical load centers. NCHRP Report 525: *Surface Transportation Security Volume 3* notes that there are many infrastructure vulnerabilities in the U.S. due to the open nature of our systems and thus problems such as accessibility to facilities and incoming utilities, IT and network security, resistance to structural damage, and adequacy of facility control and support systems.

Redundancy is important in monitoring and analyzing critical transportation infrastructure. For example, both State DOTs and Homeland Security have installed cameras and alert devices at many critical bridges and other infrastructure. A Traffic Management Center (TMC) in Orlando, Florida has a warning system for any vehicle that is parked under a key bridge for more than a certain time period; this system transmits an alert to the TMC, where staff take action to collect more information or alert the State Patrol. Sometimes DHS installs security systems alongside DOT cameras but does not share information from DHS security systems with DOT. DHS and DOT need to combine efforts and work together on redundant surveillance and information sharing that could benefit the intelligence and the emergency management/transportation sectors. Since road cameras may detect activities of interest to security officials during malevolent events, transportation officials may need to relay this information to DHS, FBI, or another organization that needs the information. Consequently, transportation agencies—while not the lead for security responses—may need to have Sensitive Compartmented Information Facilities (SCIFs), Secure Telephone Unit Third Generation (STU-III)/Secure Terminal Equipment (STE), or other secure communications and facilities including staff with clearances.

Importance of Redundancy

NCHRP Report 525: *Surface Transportation Security Volume 3* notes that system redundancy (along with response and recovery measures) may be a better approach to terrorist events and acts of extreme violence than the development of prevention systems.

If there is no redundancy, there is greater risk to a transportation system. Redundancy is essential for daily system management and operations but is crucial during a disaster. Jurisdictions are most likely to make the changes that will enhance redundancy if there is also an immediate benefit to the public. For example, a key evacuation route that is widened to ease routine traffic congestion will also facilitate improved evacuation as well as help mitigate a potential chokepoint into and out of a city. Federal assistance grants are becoming scarce and difficult to obtain, and many jurisdictions do not feel that their risks justify the enhancements. However, the same emergency response planning that is conducted for local emergencies can directly help the response to larger disasters. It is impossible to completely protect all transportation assets, so redundancy and cooperative efforts can help with disaster response in ways that a municipality or region could not achieve on its own and thus make the best use of limited funds.

Examples of Redundancy Successes and Shortfalls

An example of the benefits of redundancy during a major incident occurred after the 9/11 attacks, when roadways in lower Manhattan including bridges and tunnels provided key transportation links. Trains were able to carry victims and bystanders to safety from the WTC station located under the towers. Thousands of commuters caught trains out of the World Trade Center (WTC) station before the towers collapsed, and none of them became casualties. Simultaneously, the Port Authority was able to capitalize on the redundancy of control centers in the area to switch to a backup site in New Jersey when the New York City Command Center was destroyed, and the New Jersey Transit and New York City Transit operations deployed mobile command centers. During the same time in Washington, D.C., local DOTs and transit systems were able to successfully evacuate the area. In both the New York City and Washington experiences on 9/11, redundancy played a key role in evacuation efforts. Both of these examples also demonstrate the value of the transportation staff and equipment to emergency responders since the Port Authority, Washington Area Metro and the departments of transportation and transit worked tirelessly with city, State and Federal officials to aid the response effort.

Lessons learned from the 2003 Northeast Blackout in the Great Lakes region show the necessity of backup power and generators in support of transportation operations as well as a system for deploying them. During the Northeast Blackout in New York City, tunnel lights and ventilation systems in the Brooklyn Battery Tunnel had power to clear the tunnel of smoke and debris as planned. Redundant electrical generation systems in place also helped restore power at other key locations such as emergency control centers. These generators assisted in flood prevention efforts in subway tunnels and communications networks. However, during the same incident, the New York City subway system ground to a halt since it did not have auxiliary power generators to keep the system—which runs on electricity—functioning. The loss of electrical power made New York City transportation officials aware of the need for backup generators with independent fuel that would at least provide partial power for the subways during emergency conditions where power was lost. For electrical heavy rail commuter trains, diesel powered locomotives could be stockpiled and available for an evacuation where the power has failed.

Moreover, the 2001 Howard Street Tunnel fire in Baltimore demonstrated the importance of identifying chokepoints and the importance of redundant systems that can be used to compensate for a major transportation system disruption. One of the lessons learned was that transportation system rights-of-way are often used for the convenient placement of fiber optic cable, but the Internet was disrupted as a result of damage from the tunnel fire. Thus, the same incident that disrupted a transportation mode also disrupted a communications mode and infrastructure that could otherwise have been used to help mitigate the original incident.

Communications and Technology Systems Redundancy

The US DOT's report on the transportation effects of the Northeast Blackout shows that agencies need reliable communications technology to enable them to reach the public, responders, and each other with accurate information. Internal and external emergency plans are needed to ensure communications during a disaster. Redundancy should be considered when designing a system used to notify emergency personnel, since some communication systems may be out. Alternative methods of communication for alerting and activating emergency personnel include e-mail alerts, fax, pagers, call centers, call down lists, the Reverse 911® call system, Blackberry, two-way Nextel phones, mobile text messages, radio systems, and media announcements. Nationwide, communications bandwidth is vulnerable with regard to redundancy; the more choices among communication devices the better, and having a sufficient number of older or lower-technology devices can be a good choice.

Backup systems must be regularly tested and maintained to ensure they will be reliable in an emergency. The Federal Transit Administration's *Disaster Response and Recovery Resource for Transit Agencies* recommends that transit agencies have adequate fuel on hand prior to a disaster, as well as extra batteries for both their portable radios and cell phones; vehicular charging units available and tested to allow recharging of radios and cell phones; and backup generators capable of at least powering the fuel system, radio communications, key lighting, electrical outlets and shop equipment. It is important to maintain a variety of old and advanced communication devices, because nothing is guaranteed to work in any situation. Relying on neighboring agencies or facilities for redundancy if not previously planned and exercised can be detrimental, because during an extensive disaster they may need to deal with their own problems.

Both the Association of Public-Safety Communications Officials (APCO) International's *Homeland Security White Paper* and the just-released DHS *Tactical Interoperable Communications Scorecard Report* stress the importance of interoperability: the ability of different agencies or first responders to communicate within and across departmental and jurisdictional boundaries. The *Tactical Interoperable Communications Scorecard Report* provides assessments of interoperable communications capabilities in 75 urban and metropolitan areas nationwide, involving policies, technology, and training that enable emergency responders from multiple jurisdictions in a common community to effectively communicate within one hour of an incident. The findings identify gaps and areas for improvement; only six of the 75 cities and regions surveyed received top scores for interoperability, but the assessment noted that basic interoperability at the command level is achievable. As a national communication interoperability standard is being developed, transportation officials should plan to ensure that their communications equipment and future purchasing mirrors this standard so that they may talk with emergency managers, first responders or other officials during disaster operations.

Intelligent Transportation Systems (ITS)

ITS, including both in-vehicle and roadway components, were originally developed for operational purposes but can help provide redundancy in response to loss of transportation assets during an evacuation or other disaster response. As more technologies make their way into cars, more travelers in vehicles will have access to critical information through more means. If cellphone towers are lost due to a hurricane, ITS have the ability to utilize fiber-optic, wireless, or landline communications to get travel information to the public. By using embedded traffic controllers, traffic signals, vehicle detectors, Dynamic Message Signs (DMS), and traffic surveillance cameras, several adjacent intersections can be made to work together as one, coordinated system to help evacuation.

ITS facilitates information that can be valuable to evacuation efforts, including designated evacuation routes, support facilities and equipment and institutional and electronic integration. ITS devices such as DMS, Highway Advisory Radio (HAR), 511 telephony, Closed-Circuit Television (CCTV) surveillance cameras, Automatic Vehicle Location (AVL), Computer-Aided Dispatch (CAD), Transportation Management Centers (TMCs) and other tools originally deployed for traffic management, have been invaluable in evacuation operations. Learning from past disasters, Florida, Texas and other states have expanded the coverage of CCTV and DMS to cover the rural section of highways that may serve as evacuation routes. Other related initiatives included sharing of devices across jurisdictions, including transportation departments of various levels and public safety entities that support the evacuation. Such sharing is facilitated by institutional arrangement and technical integration of networking devices of participating jurisdictions. ITS can help respond to homeland security incidents; e.g., a Road-Weather

Information System (RWIS) in a large city can provide data on wind direction, which will enable a more effective response to a plume resulting from a chemical or biological attack or accident.

Real-time traffic and traveler information can be gathered, analyzed, and made accessible to drivers, operators, and passengers via a range of media such as radio, telephone, DMS, kiosks, and the Internet. Telematics provides reliable two-way communications between separate vehicles and between vehicles and the roadside, including emergency notification and driver information. The use of traffic signal remote access and coordination can provide better progression for evacuation routes. More and more traffic signals are equipped with remote access capabilities through wireless or wired communications. The remote access allows traffic management personnel to change the timing of individual traffic signals along major arterials in a way that promotes fewer stops. This practice is applicable in evacuation to facilitate directional movement on the evacuation route. The key logistical requirement is to develop a set of signal timing plans that can be "uploaded" in support of the intended evacuation scenarios. Data that characterize roadway conditions are also available from emergency response systems, freeway management systems, incident management systems, traffic signal controllers, electronic toll readers, and RWIS.

While cameras and signs are procured and operated by individual jurisdictions, ITS Standards developed in the last decade have greatly improved the interoperability of devices. However, many areas do not have the ability to collect real-time information because their ITS network lacks various pieces. In addition, ITS is very expensive and many jurisdictions cannot justify the expense in spite of the obvious benefits. Also, various technologies have not reached the point of being able to consistently provide the information needed, but USDOT is working to improve the technology. Some ITS have not been hardened or designed to withstand the onslaught of nature. Traffic cameras will fail at certain windspeeds or will be blown off their mountings.

Transportation / Traffic Management Centers (TMCs), Emergency Operations Centers (EOCs), Incident Command Systems (ICS) and Redundancy

TMCs are crucial to disaster recovery. They provide traffic control, incident/emergency management, and Advanced Traveler Information Systems (ATIS). TMCs gather information about current roadway conditions through means such as CCTV cameras, traffic and weather sensors, DMS, HAR, traffic signals, and ramp meters to monitor and manage traffic flow on streets and freeways. The TMC plays a key role during a disaster in helping determine routes for responders to get to an affected area and routes for citizens to leave the area. A TMC's equipment typically includes ITS, voice response systems, and Internet sites. Since the TMC will probably play an important role in disaster recovery, information it can provide is essential, particularly when it lets the public know what is occurring on roadways and other critical information. The FHWA TMC Pooled-Fund Study's *Recovery and Redundancy of Transportation Management Centers* notes that communities depend on the TMC's critical infrastructure, which must be protected against system outages. Having a redundant processing site that duplicates the TMC's capability is highly recommended. When there is a redundant, alternate processing site that can serve as a backup TMC, there may be no capability lost even if the primary site were to become unusable, which is crucial if continuous availability is required.

Emergency Operations Centers (EOCs) are central command and control facilities responsible for emergency preparedness and emergency management, or disaster management functions at a strategic level. EOCs ensure continuity of operations. Ideally, it would be desirable to have TMCs and EOCs electronically interconnected and sharing information during a disaster. With the pairing of a TMC with an EOC, TMC information and analysis is immediately available to emergency management officials via the transportation staff at the EOCs and the FEMA Disaster Field Office set up to coordinate federal recovery efforts with State and local governments.

Adoption and adherence to an Incident Command System (ICS)—as prescribed through DHS' National Incident Management System (NIMS)—can help optimize redundant resources, facilitate communication among emergency responders, and allow them to more effectively respond to disasters under certain circumstances. ICS is a system designed to allow responders to implement an appropriate integrated standard to handle incident demands without jurisdictional restrictions. The transportation sector is expected to train its staff in the National Incident Management System (NIMS) in accordance with Homeland Security Presidential Directive (HSPD)-5 and DHS guidance.

Role of Institutional/Organizational Cooperation and Planning in Redundancy

The FHWA's publication *Communicating with the Public Using ATIS During Disasters* notes that advance coordination and cooperation between or among agencies is key to utilizing the benefits of redundancy. It discusses the value of determining what types of information it is important to know in advance; e.g., who has what equipment (an inventory of how many devices there are, and where the devices are located), which agency has ownership over which devices, and which devices are—or can be—controlled jointly. Communications incompatibilities and lack of interoperability among communication devices can present a problem at the very time the devices most need to work together, which it is important to discover in advance. Workshops can help personnel from agencies involved in emergency management and transportation to be aware of devices and services that exist outside of their own jurisdiction.

Success in disaster response is most likely when the command structure is well understood, agencies work well together, and emergency responders are empowered to make decisions. Public awareness of the hazard, evacuation procedures, and especially alerting methods has been often cited as helping the efficiency and effectiveness of an evacuation. The more complex the incident, the more likely that a multi-agency coordination group (or a MACG), will be formed for operational command and control. In some cases, including when an evacuation is being planned, a transportation sector representative should be a member of the MACG. At the very least, a transportation official knowledgeable of all modal operations, safety, transportation security and ITS, should be on hand to advise the political decision maker, the Emergency Response Team Leader and/or the Incident Commander. To meet this need, more transportation personnel need to be trained in how to collect, analyze and interpret information from ITS or use ITS communication capabilities, since raw data do no good without the necessary analysis and interpretation. Transportation analysts should be included in the staff of the Planning section of any emergency response team, just as GIS specialists are now included as technical experts. Of course, they could be linked electronically to the EOC, but need to be included in planning, procedure development, training, exercises and operations.

Future Trends that Will Impact Transportation Systems' Redundancy

The following selected future trends will likely impact the transportation system's abilities to support evacuations with regard to redundancy:

- New technologies to communicate with the public: Technologies such as VII (vehicle-to-vehicle and vehicle-to-infrastructure communications) supported by development of roadside network architectures and a comprehensive wireless broadband data transfer network infrastructure, Next Generation (NG) 911, and a new emergency alert system under development by DHS/FEMA that includes automatic radio/TV/cell phone activation for critical news, provide the foundation for improved emergency communication between the public and emergency responders. These developing technologies will improve effectiveness of evacuations by enabling enhanced 911 calls from most types of communication devices. Satellite radio and television can be used to broadcast travel information including traffic and weather updates and routing to vehicles in remote areas that are outside the range of most broadcast stations. Some services now offer navigation integrated with traffic updates.
- Increased electronic intermediation of vehicle control and evolution and integration of information and safety systems: The USDOT's *Private Sector Deployment of Intelligent Transportation Systems: Current Status and Trends* notes that these technologies will allow the vehicle to adjust driver inputs and improve safety, combine adaptive cruise control and lane-keeping systems, and tie onboard navigation units to real-time traffic information, all of which will help keep vehicles flowing more smoothly during evacuations.
- Improvements in modeling tools and information collection: There are presently a number of operational tools for hurricane modeling and information sharing, and analytical tools for transportation modeling and analysis, that are being used for planning evacuations. FHWA is currently conducting a modeling inventory to help emergency managers and transportation agents know the benefits and limitations of current modeling and simulation tools on the market. These changes will enable decision makers to be more comfortable with making quick decisions on evacuating populations, enhancing redundancy. Hurricane forecasting tools have gotten much better over the past 15 years, and in the future their increasing sophistication will assist transportation officials in more effectively targeting transportation resources to move people from those areas most likely to be affected by a disaster. Real-Time and Predictive Traffic Services will greatly improve accuracy, quality, and coverage of traffic information, helping organizations anticipate traffic conditions before they occur.
- Increasing reliance on public transportation: Especially in metropolitan areas, the increasing reliance on public transportation should enhance the efficiency of evacuation operations when public transportation is integrated into multi-modal operations.
- Deteriorating transportation infrastructure: Transportation infrastructure deteriorates with time and use; changes in weather conditions causing more hurricanes, floods, and large-scale fires would increase the need to maintain and replace transportation infrastructure. Increased public investment would have to be made to ensure that the infrastructure is adequate to handle any evacuation needs. When governments at any level, but especially cities and States, experience a financial crisis, there would typically be less money available to pay for the type of road and rail improvements that support disaster management.

Conclusion

The U.S. enjoys a remarkable transportation network, with much infrastructure and alternative travel modes available. The transportation community's ability to manage and operate the transportation network has improved considerably. The level of technical sophistication in the transportation network continues to rise through increasing use of ITS, VII and other advanced technologies. However, there are many infrastructure vulnerabilities in the U.S. due to the open nature of our systems. Real-world disasters have shown that when redundancy has not been utilized to compensate for loss of assets during evacuation or disaster response, transportation systems can be overwhelmed. When that happens, it is typically due to inadequate communications— in one form or another. If transportation agencies have not previously trained to and coordinated how they will share information, facilities, or equipment with other transportation organizations or emergency responders, redundancy will not be available when it is needed. And even with an abundance of communications equipment, there will be problems if there is no interoperability.

So, in general, while the Nation's transportation systems have considerable physical capabilities and great potential redundancy to compensate for loss of transportation assets resulting from natural disasters or terrorist attacks, more coordination and training are needed to better use what we have when we must depend on our transportation systems to work for us under stress.

CONSOLIDATED COMMENTS FROM MEMBERS OF THE BLUE RIBBON PANEL OF TRANSPORTATION EXPERTS - PAPER 4E-02

Several reviewer combined their comments as follows:

Comments from Paper 4E-01 have applicability in a "redundancy" context as well as "evacuation".

Adding cross training of employees to operate various modes (including logistics, union issues, compensation, etc.) with appropriate Memorandum of Understanding among entities as a key element going forward.

Redundancy requires breaking down jurisdictional and institutional barriers among modes, both operationally and cost sharing.

Redundancy for critical infrastructure information sharing is also required (ITS, CCTV, intelligence data, etc.). Traditional barriers, including law enforcement and civilian, need to be integrated and managed collectively.

The accuracy of the state redundancy successes associated with 9/11 should be reviewed. Note that PATH trains stopped by the time the second tower was hit. Some vehicular tunnels were closed and commuter train operations ceased for nearly 6 hours.

Redundancy aspects should be included in the ongoing transportation planning and programming process as one measure to establish program and project priorities. Funding shortfalls and limited financial capabilities will likely detract from the effectiveness of the potential redundancy benefits.