Learning from Urban Disasters: Summary of a Workshop

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The collapse of the World Trade Center in New York City on September 11, 2001, was one of the worst urban disasters in the history of the United States. Almost 3,000 people perished as a result of the disaster. The economy was dealt a severe blow, the consequences of which are still felt today. When the World Trade Center was first built, its approximately 1.25 million square meters of office space accommodated about 40–50,000 people (Extreme Events Mitigation Task Force, 2002, p. 52). The number of telephone lines installed in the towers was similar to that found in cities such as Cincinnati or Copenhagen[1]. The collapse of the World Trade Center raised a large number of research questions related to understanding what happened on that day, why the buildings collapsed, how agencies and individuals responded to the event, how civil infrastructure systems were affected, and how the lessons learned can be used to prevent similar disasters from happening.

To address the many issues raised by the September 11th disaster, the National Science Foundation (NSF) awarded Small Grants for Exploratory Research and, through the Natural Hazards Research and Applications Information Center at the University of Colorado, "Quick Response" grants, to obtain information that might not be available later. NSF provided funding to the Institute for Civil Infrastructure Systems (ICIS) to convene researchers and others directly involved in response activities at a workshop to exchange experiences and knowledge. The workshop's objective was to promote connectivity among members of the research community for future collaboration and between researchers and emergency managers to advance research on catastrophic events of the kind that occurred on September 11th.

On December 12 and 13, 2001, ICIS hosted these researchers, NSF, and officials and other managers involved in the aftermath of the September 11th disaster to identify some of the key problems and issues associated with the attack and potential research themes to address these issues. Research participants came from many disciplines, and included engineers, urban planners, geographers, sociologists, political scientists, and other academicians. They came from about two dozen universities in over a dozen states in all regions of the country. Managers who were involved in response to the September 11th disaster participated as speakers at the workshop. They included professionals from federal, state, and local government; officials in emergency management and key service sectors such as environmental protection and transportation; the utilities; health institutions; the National Institute of Standards and Technology (NIST) and the American Society of Civil Engineers investigative team.

This report describes the major themes and lessons discussed at the workshop. The research areas included are structural engineering, building performance, and fire safety; civil infrastructure systems; data and information gathering; agency coordination during response; and behavioral responses. After the presentations made at the workshop, a number of participants discussed future research issues and cross-cutting themes. The results of these discussions are presented in the last section of this paper.

Readers should note that the summaries given here reflect presentations made at the time of the workshop, and that the researchers' observations and conclusions may have changed since the workshop was held. Many of the presentations at the workshop were developed into papers for this volume, and more detailed descriptions of the projects and their updated conclusions can be found by referring to other selections in this book.

Structural Engineering, Building Performance, and Fire Safety

Several structural engineering research issues are associated with the collapse of the World Trade Center. These include understanding what happened, why the structures collapsed, and how the buildings performed during extreme conditions. A number of structural engineers and related specialists began to work immediately at the site of the disaster to address these issues. Although the World Trade Center collapsed, a number of neighboring buildings that sustained serious damage did not, including the Verizon building (which was damaged by debris). Engineers were interested in finding out why those structures did not collapse. Moreover, the World Trade Center towers remained standing for a sufficiently long period of time to allow around 20,000 people to evacuate the towers. This suggests that future designs could provide for even greater egress during such conditions, allowing more people to survive a similar catastrophe.

Preliminary Impressions of the World Trade Center Disaster, Post-disaster Reconnaissance, and Perishable Structural Engineering Data Collection[2]

Researchers Abolhassan Astaneh-Asl, W. Gene Corley, and Michael Bruneau, who were working in this area, were faced with a serious challenge. The cleanup efforts and response at the site began to proceed at a rapid pace. A large amount of steel from the collapse was taken to New Jersey where some of it was being recycled. By the end of 2001 over 150,000 tons of steel were processed and recycled. Hence, the clean-up efforts did not allow some researchers to collect as much data as they would have liked. Structural engineers tried to save samples of the steel to attempt to understand the collapse. The column trees and core columns were coded and had stamps or engravings that identified their location within the structure. In addition, photographs and videos were collected at the site to aid in the analysis. Such data was necessary to find out what components of the structure were significant from a structural point of view.

One of the main research efforts was to establish a sequence of events for the collapse. The two towers were very similar but not identical. The typical floor plan included roughly 1-meter spacings. The core was made up of steel columns and was there for the purposes of providing elevators, stairs, and other services. The exterior of the buildings provided all lateral load resistance. Was the collapse of the towers initiated by the collapse of the floors, caused by heat, or due to buckling? What happened on different floors? It appears that joints were the first to go where fire was intense and then the outside columns buckled. It also appeared that the inside columns did not buckle but instead collapsed after the outside columns collapsed.

Early reconnaissance work at the site was also carried out with the goal of allowing researchers to better understand how techniques from earthquake design and engineering could be used to prevent this kind of urban disaster. Two kinds of debris were analyzed for this purpose: impact debris collected after the collapse, and falling debris resulting from the collapse of the towers or collateral damage. In order to gain insight in this area, it is necessary to understand how the load is distributed when certain components of a structure are removed. For instance, the façade of 130 Liberty Plaza was pierced over many floors yet the structure remained standing. What happens when you remove a column from a building? Why did this structure survive?

Buildings that use floor diagram systems can arrest projectiles because every beam is continually connected to columns. Such systems have a desirable feature that really helps, and it is that loads can find alternate load paths. There is enough redundancy in those buildings so that it would probably take the loss of three columns before they would collapse. If elastic capacity is exceeded it is still possible to have plastic capacity. One lesson learned from the Northridge earthquake is that better beam connections are needed. These lessons are also applicable to the prevention of future urban disasters.

Fire Safety Aspects of the World Trade Center Disaster[3]

A critical part of understanding the World Trade Center collapse is the effect of fire, as explored by Frederick W. Mowrer. A number of significant research questions about this aspect of the disaster have emerged, including the effect of jet impact on fire safety systems; the role of jet fuel on the ensuing fire; the effect of fire on the structural integrity of long span steel joists; human behavior throughout the event; and the question of why the World Trade Center collapsed but the First Interstate Bank Building in Los Angeles and the One Meridian Plaza Building in Philadelphia did not, despite being subjected to severe multi-floor fires. In the case of the World Trade Center collapse, both planes that struck the towers went in at an angle and as a result the fire started in several floors simultaneously.

Conditions in the World Trade Center before September 11th were important in trying to understand what happened. The condition of fireproofing applied to steel structural members needs to be considered. The use of long-span steel bar joists to support the floors as well as the columns requires evaluation, particularly because these floor joists were part of the primary structural frame of the buildings.

Another question for fire safety research is the effect of the jet impacts on fireproofing, structural stability, exit stairs and elevators, ventilation systems, and automatic sprinklers. The World Trade Center towers were retrofitted with sprinklers but were not originally designed with them. Similarly, the role of the jet fuel is of interest. Much of the jet fuel burned outside the buildings and the remainder served as a very large accelerant. Most of the jet fuel must have burned in about 10 minutes or shortly thereafter. The results of such research will allow future designers to improve building performance in order to make this kind of outcome less likely.

Research Needs in Structural Engineering and Fire Safety[4]

More research is necessary in several areas, according to W. Gene Corley. Research will be carried out in the short and medium term in areas such as structural fire effects and protection; building egress; and search and rescue. The main research needs for structures are robustness, redistribution of loads, and connections. There is simply not enough knowledge in these areas. Connections are always considered a problem for structural engineers. More research is needed about fireproofing, how fire spreads, temperature rise, combustibles, and connections. According to some experts, this is where the largest part of the research funds should go. Fireproofing allows for enough time to put the fire out or to let it burn itself out. While what we have in buildings may burn like wood it's no longer wood and that's what we need information about. Most of the available research on the potential effect of combustibles was done on wood materials. There is little or no information in the literature about fireproofing connections. In terms of search and rescue, more research is needed in detection and locators, access, and rescuer safety.

Some preliminary research cost estimates are: $12 million for structural engineering; $28 million for fire effects and protection, where much modeling is needed; $8 million in the area of egress, where many interviews should be carried out to ask people how they came out of the towers; and $12 million for search and rescue.

Impact on Civil Infrastructure Systems

The collapse of the World Trade Center had a profound impact on civil infrastructure systems in the area. Despite the losses, most systems proved to be resilient and service was restored within short periods of time. Transportation sustained the greatest damage. The PATH (Port Authority–Trans-Hudson) train and the 1/9 and N/R subway lines sustained severe damage and service interruptions. The Holland Tunnel was also disrupted. A key subject for future investigation in the area of infrastructure systems is the role played by the various agencies responsible for these services in responding to the disaster.

Improved Security and Management of Underground Infrastructure Systems[5]

A broad area of research on infrastructure systems investigated by Thomas O'Rourke relates to improved security and management of underground systems such as electric power, water distribution, telecoms, transportation, natural gas, steam, and wastewater conveyance. Specific research goals include documentation of September 11th infrastructure systems performance; comparative analysis with infrastructure system performance after earthquakes; and developing a methodology for assessing interdependencies. Lessons drawn from infrastructure system performance during events such as September 11th involve the water distribution and electric power systems. New York City has 6,123 miles of pipeline. This is comparable to the system in Los Angeles, but is packed in 1/5 of the area. Heavy damage to underground water pipelines resulted in serious loss of pressure from hydrants surrounding the World Trade Center site. Substantial water was provided by fireboats pumping from the Hudson River. The way in which electric power is configured into local distribution systems provided a very resilient overall network that allowed for the preservation and rapid restoration of power in the World Trade Center area. New York City has the densest electrical load in the world, and it is a highly compartmentalized system.

The dense nature of infrastructure systems in New York City also suggests that disruptions can cause major damage through a cascading effect. Such incidents are comparable to what happens during extreme events such as earthquakes. Several research projects funded by the National Science Foundation related to interdependencies in infrastructure systems. The interdependencies and their performance during extreme events can be evaluated using information technology. The tragedy of September 11th resulted in a willingness to share information that should benefit research in this area. Unfortunately, such information is also viewed as having a detrimental value, as people believe it can be used for terrorist activities. If such information is not shared, researchers will not be able to fully understand what happens during an urban disaster such as the collapse of the World Trade Center.

Developing and Planning Infrastructure Systems in the Aftermath of Extreme Urban Events[6]

Today, planners and developers are trying to promote even more density. For many reasons it is not clear how to approach the issue of having large concentrations of workers along with a transportation network under one building. Discussions about shorter buildings and less density have not taken place. Implicit to this discourse, according to Cruz Russell, is the understanding that downtown needs a renewed commitment to developing the World Trade Center site, creating the critical mass of class A office space required to sustain a substantial workforce and attract future business development.

Agencies such as the Port Authority of New York & New Jersey found it difficult to plan ahead and find the time to think about what to do next in the immediate aftermath of the September 11th disaster. Urgent activities such as debris removal required a tremendous amount of work and interdisciplinary attention. Engineers estimated that it would take 24 months to restore PATH service with some kind of temporary service, assuming a very rapid schedule of work.

Such daunting tasks made it difficult to think about how to replace and restore downtown's office infrastructure in a timely fashion. There are very few places that can be developed in Manhattan that consist of 6x6 contiguous blocks situated over transportation networks, especially places that have the economic impetus that the World Trade Center had. This site represents important development challenges and opportunities.

The Port Authority of New York & New Jersey and agencies like it will be looking at fortifying resources such as tunnels and bridges, ferries and rail crossings, and attempting to create both the physical and human infrastructure systems that will withstand the reality that society now will have to accept, after September 11th.

Transportation Systems

The transportation sector suffered severe disruption after the collapse of the World Trade Center. Research efforts in this area center on understanding the disruptions to travelers caused by damage to transportation infrastructure, the coordination of response efforts in the sector, and the behavioral response of transportation users.

Impact of the World Trade Center Collapse on PATH Tunnels and Subway Lines[7]

Damage to public transportation systems in the vicinity of the World Trade Center was extensive, as noted by Joe Englot and Joseph N. Siano. The PATH station beneath the complex was compromised by the collapse of the World Trade Center. There was flooding in the PATH tunnels and two of them had to be plugged with concrete to avoid flooding the rest of the system. Users responded by going to Christopher Street via the 33rd Street line and changing to the Metropolitan Transportation Authority's subway service. However, these stations were not designed to be used by such high numbers of people. The 1/9 subway train also sustained severe damage, as it was essentially destroyed by the collapse of the buildings. Approximately 1,200 linear feet of tunnel were damaged or filled with rubble.

Some areas of the PATH station were intact after the towers' collapse, but damage was expected to be total because of the removal operations above and the heavy machinery being moved around above the PATH stations. The presence of many utilities in the area complicated restoration efforts. The steps needed to restore the PATH included recovery of human remains, debris removal, stabilization of the bathtub wall, removal of PATH tunnel plugs at Exchange Place, rehabilitation of PATH tunnels under the Hudson River, construction of a temporary PATH station at the World Trade Center site, planning and coordination for a new permanent PATH station, and actual construction of a permanent PATH station.

Disruptions in transportation posed serious problems for people who needed to commute to work from areas such as Jersey City and Brooklyn. As a result, restoration of service to the N/R subway line, and planning for reconstruction of the 1/9 line were high transportation priorities.

Coordination Efforts in the Transportation Sector[8]

In considering the transportation coordination efforts after the World Trade Center collapse, as David Woloch did, it is important to remember that responsibilities were diffused among many different players. Even within the City of New York Mayoralty, there were many different agencies with transportation functions, including the Department of Transportation, the Department of City Planning, the Department of Design and Construction, and the Police Department. Other entities included the State Department of Transportation, the Port Authority of New York & New Jersey, and the Metropolitan Transportation Authority. Coordinating these agencies is a very difficult task under the best of circumstances—but in the wake of September 11 this coordination was crucial.

The City Department of Transportation is primarily responsible for both maintaining and regulating the uses on the City's streets and sidewalks. With the primary transportation responsibilities after September 11th, the Department of Transportation needed to immediately develop and implement new solutions to allow for mobility to and within lower Manhattan—and in doing so needed to work effectively with its many partners.

On September 25, as the lower Manhattan business district tried to get back on its feet, motorists began to return to the roads. But while traffic actually appeared to be moving in Manhattan there was absolute gridlock in Brooklyn, Queens, and New Jersey. In addition to the reduced roadway capacity in the World Trade Center area and the closure of crucial corridors and crossings (including the West Side Highway, the Holland Tunnel, and the Brooklyn Battery Tunnel), security checks at the remaining crossings were vigilant and created long vehicular queues outside of Manhattan. As a result, that morning motorists faced a commute that took hours. It quickly became clear to the Department of Transportation Commissioner Iris Weinshall and her staff that all bets were off and unusual measures were called for.

The most important step recommended by the Commissioner—and accepted by Mayor Giuliani—was to implement a single-occupancy-vehicle restriction during the morning rush hours into midtown and lower Manhattan. (Although illegal under normal circumstances, such a ban was possible through the post-September 11th Mayoral Emergency Order). The ban reduced vehicular volume during the morning peak period as many solo drivers appeared to car pool or take transit. There was also a spike in volume before the peak (5 a.m. to 6 a.m.) and after the peak, helping to spread the traffic volume throughout the day. The ban's success would not have been possible without extraordinary interagency cooperation. It required the participation not only of the Department of Transportation and the Police Department but also the Metropolitan Transportation Authority (responsible for the Midtown Tunnel) and the Port Authority (responsible for the Lincoln Tunnel).

A year and a half later the ban continues (with shorter hours and only into lower Manhattan). Other measures taken by the City Department of Transportation, including establishing a Brooklyn Ferry route and providing bus priority space in lower Manhattan, also continue. The aftermath of September 11th brought out creativity and coordination among agencies in a manner that fostered long-term transportation and transit improvements.

Impacts of Extreme Events on Passenger Travel Behavior[9]

The events of September 11th affected not only the transportation system but also its users. One research area is the assessment of the behavioral changes that took place as a response to the disaster. A research project conducted by José Holguín-Veras included analysis of data, assembling and selecting a panel, definition of surveys, and estimation of behavioral models. The behavioral models estimated and quantified the role of September 11th on the mode choice process for air travel. This research should contribute to a better understanding of the changes in travelers' behavior after extreme events, and how transportation agencies should deal with them.

Energy and Electric Power

Damage to Energy Infrastructure during the World Trade Center Collapse[10]

The provision of electric power to approximately 13,000 customers in the World Trade Center area was affected by the September 11th disaster, according to Elie Chebli. A 13-kilovolt (kV) substation was lost when the first tower was hit. The summer demand of these customers was approximately 450 megawatts (MW). This load area is the equivalent demand of the city of Hartford, Connecticut. The share of this total used by the World Trade Center buildings was 90 MW, which is equivalent to the amount of power used by the city of Albany, New York. Despite the magnitude of the disaster, Con Edison managed to stay within its design standard because there is a lot of redundancy built into its system. The five 138-kV transmission lines feeding the substation in lower Manhattan were de-energized as a result of the collapse of World Trade Center buildings 1, 2, and 7. Measures were taken to re-energize those feeders. They were first isolated from the destroyed buildings 1, 2, and 7 so that they could be re-energized from another substation in the lower Manhattan area. In addition to providing electricity, Con Edison also supplies the gas system and steam, and several gas and steam pipes also were interrupted.

Resiliency in Energy Infrastructure Systems[11]

Elie Chebli also explained that internal power distribution at the site was owned by the Port Authority of New York & New Jersey. Power distribution had an N-2 design, which means that two 138-kV lines or two power transformers or two 13-kV feeders may be de-energized and the remaining 138-kV feeders, power transformers, and 13-kV feeder are still able to carry the energy load to customers. Five networks totaling approximately 450 MW were lost. The first estimate for repairing the first 138-kV feeder was 14 days. Engineers located places to excavate for splicing the 138-kV cables. The cables then needed to be frozen before being spliced. The time estimate for repairing the feeder was changed because splicers worked around the clock in shifts. Only six days after the collapse, the first 138-kV feeder was repaired and two hours later another was repaired. As a result of the system's design and rapid repair work, there was relatively little service interruption. The performance of the electric power systems during the disaster provides researchers with valuable lessons about system design and resilience that will be useful when addressing other urban disasters.

Telecommunications

Research Issues and Characteristics of the Telecommunications Sector after the World Trade Center Disaster[12]

The main research issues in telecommunications were the performance of the various systems during the emergency and immediate response to September 11th, the characteristics of service outages and system failures, how they were repaired after the initial response, and the nature of the recovery process. Anthony Townsend noted that wireless communication was needed for the emergency response since emergency workers needed connectivity at Ground Zero. AT&T provided unlimited telecommunications for workers. Temporary cell sites replaced destroyed antennas.

The World Trade Center served as a broadcast platform for the New York metro area. Many antennas were located there and the damage to the sector from the disaster was extensive. The collapse also strained the sector as demand for services skyrocketed. AT&T's long-distance service recorded a historic call volume on September 11th with about 431 million calls. The

AT&T emergency response was similar to that of other events, such as the 1994 Northridge, California earthquake. Wireless carriers were not as prepared as AT&T. There were enormous, ongoing, city-wide cell phone service breakdowns in other cities as well, including Boston and Washington, D.C. There were too many calls and not enough capacity. In addition, there was no system in place to set priorities on the calls.

With regard to Verizon, there were outages in lower Manhattan that resulted from damage to 200,000 voice lines, 3.6 million data circuits, 10 cell sites, and other facilities. Despite this heavy damage, phone service was restored. Verizon is rebuilding 140 West Street.

The response of corporations and their effect on the telecommunications sector is also the subject of research, as companies dispersed and there was an exodus to other locations such as midtown Manhattan, Jersey City, Stamford, and Westchester. The resulting competition helped the telecommunications sector through the profusion of carrier hotels, which still tend to be clustered.

Online services performed well because the internet is based on distributed, product-switched networks. The same happened in Serbia during the U.S. bombing of that country's communications systems—the internet survived very well.

Water Distribution and Environmental Services

Performance of the Water Distribution System after the Collapse of the World Trade Center[13]

One of the main concerns in the performance of the water sector after the collapse of the World Trade Center towers was the provision of water for firefighting activities. Diana Chapin explained to the workshop participants that the collapse caused nine water mains surrounding the site to break, which resulted in a loss of water pressure to such a degree that it was insufficient to meet the needs of the Fire Department. However, by about 10:30 p.m. the New York City Department of Environmental Protection, the city's municipal water supplier, was able to restore water pressure to 40-50 psi without having to supplement the system with Hudson River water pumped from the fire boat. Interagency communications immediately after the collapse were problematic. However, communications were reestablished within a short period via face-to-face communications at the command post and use of the agency's standard 800 MHz radio system.

The deeper sewer system sustained much less damage than did the water distribution system, with only one sewer collapsing and another slightly damaged by a 30-foot piece of structural steel. The Department of Environmental Protection sustained very little damage compared to other utilities. The damaged mains are being replaced with concrete-lined ductile iron mains of the same size (12- and 20-inch mains) at a total estimated cost of $14 million.

Watershed Security and Environmental Monitoring of Water Systems[14]

Another major concern in the water sector was enhancing security. According to Diana Chapin, the system is large, and has significant redundancy. Most chemical and biological threats are not effective. Since the September 11th disaster, additional actions were taken both upstate and in New York City. There was no public access to these facilities for security reasons after the attacks. Under the direction of the Department of Environmental Protection, a security action plan was developed by the Bureau of Water Supply and the Department of Environmental Protection's police. There was also consultation with the other law enforcement personnel.

According to David Lipsky, the Department of Environmental Protection has a network to monitor various environmental indicators, including residual chlorine, pH, and others. The department also decided to enhance some chemical and biological monitoring after the attacks. There are many important issues that arise in trying to set up a monitoring system under emergency conditions. For instance, when it is not possible to rely upon air transportation—redundant or local lab support services are needed. It may also be necessary to rely on local expertise to address ancillary risk management issues, such as deciding what type of monitoring programs to implement. This also means that there is a need to address the training and expertise of local teams. In addition, implementation of an effective monitoring system may be difficult if access to internet data is restricted. Another challenge is to provide smaller water companies with adequate and effective direction.

Under such conditions, there is a need for a defensible objectives-based sampling process. For example, should the focus be on risk- or hazard- or exposure-assessment? A strong quality assurance/quality control plan is required for proper data interpretation and comparability. There is also a need for a strong environmental team to make decisions on data, and to identify and qualify labs to support monitoring activities.

Another set of challenges is associated with managing expertise and data. In an urban disaster there may be too many experts offering opinions, which could result in the amplification of risks and the creation of much data but little useful information. In addition, experts may not have ownership of problems or familiarity with the monitoring system. Similarly, there are lots of agencies offering to help and it is necessary to have a coordinated risk management-based approach in order to develop targeted strategies.

September 11th demonstrated a clear need for comprehensive risk management research. It is impossible to prevent all risks but it is possible to effectively manage risk. In order to do this it is necessary to develop defensible risk management programs. This suggests the need for continuing research on early warning monitoring systems. One research issue in this area considers the pros and cons of high-tech vs. low-tech systems. The more high-tech the system is, the more difficult and expensive it will be. It is also necessary to more clearly define risk management objectives.

Interdependencies among Civil Infrastructure Systems[15]

Infrastructure systems are physical components and services that are used or consumed by the public. These infrastructure systems are dependent on each other. For example, if the Metropolitan Transportation Authority is to provide its services, it must have power. There are many examples of interdependencies in New York City among Con Edison, Verizon, the Metropolitan Transportation Authority, and others. Coordinating efforts among these players is sometimes challenging, because private suppliers are not comfortable with sharing proprietary data.

One of the most pressing research activities in the aftermath of September 11th was the collection of perishable information on critical infrastructure interdependencies and supporting inter-organizational coordination of interdependent critical infrastructure systems, as conducted by William Wallace. This allowed for the development of tools to visualize existing and potential interdependencies, to shield proprietary data, and to integrate initial approaches with ongoing efforts. Models of network flows, decision theory, cognitive science, and data visualization were used in these research efforts. Research on the interdependencies of these systems will aid planners and developers in developing strategies to piece back infrastructure systems in a timely fashion after an urban disaster.

Data and Information—
Security Issues vs. Public Access to Data

Information and data are critical in coordinating activities after an urban disaster and in carrying out research to understand what happened and what lessons can be learned. Research in this area includes data collection, data quality and accessibility, information technology firms and their response to disaster recovery, representation of data and information in the media, and disaster assistance in the for-profit sector.

Digital Data Collection Technologies[16]

Research conducted by J. David Frost after the September 11th events used new digital data collection technologies. Traditional data collection is subjective and results in different levels of detail or types of data being gathered. A systemic approach to data collection is very important. Field reconnaissance equipment included palm pilots, digital voice recorders, digital video cameras, and hand-held geographic positioning system (GPS) technology. Laptop computers were used for data analysis. Integrated data acquisition and analysis software allowed for the recording of feature damage, locations, and photographs. New software was also used that allowed for the rapid assimilation of data from multiple users and to query data based on information type and individual features.

Data Accessibility and Quality[17]

There are many issues related to data accessibility and quality. This is one of the greatest challenges to research projects after an urban disaster such as that on September 11th, as noted by Susan L. Cutter. Data can be both public and private, and even confidential. The political climate with data sharing among jurisdictions varies widely. There is a need for spatial data infrastructure before urban disasters. Data need to be stored in more than one location. After the attacks, public data access was discussed in terms of national security vs. the community's right to know. Many researchers consider public access to this data to be critical. For instance, most environmental data is in the public domain, yet access to some of it was limited.

Response and recovery efforts after urban disasters may result in data restrictions that challenge the Emergency Planning and Community Right-to-Know Act (EPCRA), which establishes requirements for federal, state, and local governments; tribes; and industry regarding emergency planning and right-to-know reporting on hazardous and toxic chemicals. The provisions of the act help increase the public's knowledge and access to information on chemicals at individual facilities, their uses, and releases into the environment (U.S. Environmental Protection Agency, 2000). Despite the importance of environmental information, certain internet sources of data were removed from public access after September 11th.

Patterns of Media Coverage of the Attacks on the World Trade Center[18]

In the area of media analysis, a research project undertaken by Christine Rodrigue produced a timeline of events and examined 288 articles on the September 11th disaster from the on-line edition of the *Los Angeles Times*. Ten principal themes dominating the articles emerged in the analysis, including context, diplomacy, investigation, military, and others. In the first three weeks after September 11th, the coverage was focusing on a relatively wide array of topics, especially reactions, military, investigation, and restoration. In the last three weeks, the coverage had begun to narrow to two main themes: the military and investigation.

The ten themes could be grouped further into three main narratives: war, disaster, and crime. According to the researcher, coverage of the World Trade Center and Pentagon attacks shifted into more of a war narrative than a disaster narrative very early on. The military-related categories of military, diplomacy, and mitigation accounted for 31% of the first six weeks of front-page coverage, compared to 36% in the disaster narrative and only 14% in the crime narrative. Stories of the disaster, however, dominated only the first two weeks of the coverage; the war story took over as the dominant narrative by the third week and remained dominant for the rest of the study period.

On the other hand, the context of the attacks was poorly drawn out, garnering only about 1% of the front-screen stories. As in many other disasters, context is subordinated to sensation, in this case, the images of the planes striking the towers, the fear of anthrax, and the furious military response in Afghanistan. The abrupt transition in dominance from the disaster narrative to the war narrative almost certainly did not coincide with the easing of victims' needs and those of the two hard-hit cities.

The recommendations of the project to those non-governmental organizations and victim advocacy groups working in large-scale disasters to keep news coverage focused on the victims and their needs are to try to generate "newsworthy" events, including demonstrations; to cultivate personal relationships with particular reporters; and to consider using the internet to get stories out.

Agency Coordination during Response

The magnitude of the collapse of the World Trade Center resulted in the need for an unprecedented level of agency coordination. Such efforts were led by the New York City Office of Emergency Management. They included interagency coordination, coordinating utilities, communicating risks, coordinating the private sector, managing volunteers, managing emergency efforts at the Federal level, victim information management and victim assistance, and others.

The New York City Office of Emergency Management and Coordination[19]

Michael Berkowitz and Mary Ann Marrocolo explained that the role of the New York City Office of Emergency Management is to serve as incident coordinator. This includes coordinating the integration of emergency and recovery efforts. The collapse of the World Trade Center resulted in about $83 billion of damage to New York City's economy, the loss of 125,000 jobs, and the destruction of 15 million square feet of office space in six buildings.

The Office of Emergency Management was located in building 7, so a new place was needed immediately. The office moved to Pier 92. Over 300 people per shift worked out of Pier 92. Some of the logistics and field coordination activities included coordination and planning of all onsite resources such as urban search and rescue, the U.S. Public Health Service, the New York Fire Department, the New York Police Department, the Red Cross, the Department of Transportation, the Port Authority of New York, the New Jersey Police, and others.

The damage to infrastructure systems was extensive. Con Edison lost a substation but, given redundancy in the power system, was able to continue operating in the area. In the future, this redundancy may need to be dispersed throughout the system. Verizon's building was located at West Street. That was a major switching point for the network and many of the cables were damaged. Such extensive damage also required much interagency coordination.

Another area of work for the Office of Emergency Management was debris removal, which was the costliest and most difficult operation. This consisted of organizing the haul of 1.65 million tons of debris from Ground Zero to five collection sites at the Staten Island landfill, Hamilton, 59th Street in Brooklyn, Pier 6, and Pier 25.

In addition, there were many activities related to health, such as environmental testing, worker and work site safety, and coordination of the five Disaster Medical Assistance Teams operating at the site.

Numerous human services were provided to the public. These included the Disaster Assistance Services Center for families of World Trade Center victims and those displaced by the attacks; the management of volunteers and donations; and respite centers for relief workers. The latter included meals, mental health services, and special events. There were about 12 million meals associated with the site.

Legal issues addressed included spearheading negotiations to obtain Pier 92 for the Office of Emergency Management and coordinating agencies; obtaining the required permits for emergency relief efforts and re-opening the Fresh Kills Landfill; and the declaration of an emergency. In the area of public relations and communications, the Office of Emergency Management coordinated the assembly and dissemination of pertinent information, and the Joint Information Center controlled the flow of information for a consistent message.

In terms of economic recovery, the Office of Emergency Management worked extensively with businesses to coordinate activities. Another activity involved shrinking the restricted zone. There were steady efforts to re-open closed areas of the World Trade Center area to allow vehicles, pedestrians, businesses, and residents back into the vicinity. In addition, there was a continued state of emergency, with the area around the World Trade Center being largely closed and transportation being very difficult. In order to facilitate transportation, the Office of Emergency Management operated buses through Trinity and West streets, and coordinated efforts with the Department of Transportation, the New York Police Department, the Metropolitan Transportation Authority, and other agencies in order to allow downtown access for those affected by transportation limitations.

The main lessons learned from this experience suggest that detailed planning pays off. However, this brings up the emergency management dilemma of managing all hazards vs. being hazard-specific. The best plans must include specific recommendations but also be adaptable and substantive. An example of where these characteristics are desirable is in the area of donations and volunteer management. In addition, the issue of credentials should not be forgotten: controlling access to a disaster site is crucial.

The Role of the Federal Emergency Management Agency in Coordination[20]

The Federal Emergency Management Agency (FEMA), as much as any other agency, was confronted with a new situation, Randolph Langenbach reported. It has been a couple of generations since Americans faced these sorts of threats. People at FEMA were asked to think outside the box. An Urban Hazards Forum was planned, and FEMA was one of the sponsors. Hazard mitigation in a natural disaster is a relatively easy issue, and benefit-cost analysis is required for natural hazards mitigation. In terrorism it is very difficult to do this type of analysis. There is scientific information on how often earthquakes or hurricanes take place. In terrorism this is not easily available. By lowering the risk of terrorism in one place you may well be increasing it in another, so overall benefits are not necessarily obtained. Political scientists need to be involved in discussions about coordination in order to try to understand the fundamental problems behind this type of disaster. It is also important to understand how people outside the United States view this country and what can be done about it. It is also necessary to expand the lessons learned from the September 11th attacks beyond terrorism to fire and explosions in high-rise buildings. Fires can result from a number of causes, not just terrorism. There are many fire safety issues to be addressed through concerted research efforts, including providing better tools for deciding whether rescuers should enter buildings under extreme conditions; and exploring the many technical problems associated with using helicopters to respond to fire in a high-rise building. These are areas of research that should be explored by FEMA.

National Institute of Standards and Technology's Public-private Response Plan to September 11th[21]

S. Shyam Sunder observed that the collapse of the World Trade Center was the worst building disaster in human history, resulting in unprecedented death and destruction. Never before did 400 emergency respondents lose their lives in a single incident. No one was prepared for the dramatic collapse of an occupied building of that magnitude. The disaster had the effect of uniting industry and public sector agencies. There was a multi-agency, public/private program established and partially funded with participation from key private sector organizations. Some of the issues and concerns that emerged as a result of the unexpected collapse of the World Trade Center were changing community expectations of tall buildings and the codes and standards that regulate them. Discussions about the pros and cons of the codes and standards used in 2001 relative to those used in the 1960s are likely to continue. The technical lessons from the collapse of the World Trade Center are relevant to the future of all tall buildings. A key observation is that the buildings performed much better than would be expected under such abnormal loads. There was extreme impact damage to the towers' columns, especially to the exterior columns. The initial National Institute of Standards and Technology response was a code comparison study for the Federal Emergency Management Agency and a 30-day study of repair and rebuilding for the Pentagon.

Interagency Coordination Research[22]

A broad area of research was observing and documenting the inter-organizational responses to the September 11th disaster. About 450 organizations responded to the World Trade Center disaster. The main research issue for John Harrald was understanding how a response to this type of urban disaster is coordinated. He used a number of research tools, including construction of a chronology/timeline, and agency-specific data such as situation reports, media resources, interviews, and other documents.

The findings indicate that the Pentagon response was very effective, and the response system designed for natural disasters is considered effective for terrorist attacks such as the World Trade Center collapse. The long-term implications for research are that a better understanding of multi-organization systems is needed. One of the interesting things about this case is trying to understand and document why things went so well despite the jurisdictional issues associated with trying to coordinate this kind of response.

Public/Private Sector Coordination Efforts[23]

Interorganizational coordination efforts were also complicated by the fact that the private sector played a very important role in the response to the September 11th disaster. Hence, one research issue, examined by Richard T. Weber, focused on the challenges of collaborating across the public and private sectors. Research efforts in this area began about a week and a half after the event. The study revealed that businesses such as Con Edison, security companies, Keyspan, Verizon, and many others were directly affected by the disaster. Some of them helped out directly with the recovery efforts according to their role and area of expertise. For example, AT&T provided 3,000 phones and cell phone lines. Some of these companies' activities were not well coordinated, while others were. A major issue was checking who was moving in and out of the disaster site. Information was scarce and this was a problem for the private sector. Eighteen million square feet of office space were lost, and an effort was made to find new office space to keep these businesses in New York City. Debris removal was another challenge for the public and private sectors. For example, the Federal Emergency Management Agency had to investigate the alleged theft and selling of steel from the World Trade Center. The study also examined changes made to evacuation plans after the 1993 World Trade Center bombing and how these changes affected the number of lives lost in 2001.

Interagency Coordination during Response in Other Locales[24]

Response efforts on September 11th were not confined to New York City, Washington, D.C., and Pennsylvania. In Oregon, research about response efforts to the disaster centered on the evaluation of interagency communications. Robert Parker reported that surveys were carried out and followed up with focus groups. The responses obtained suggest that agencies within that state had a clear understanding of their roles. But they also suggested that there is overreliance on standard communications. There is no extensive evidence of back-up communications systems. Out of 22 agencies surveyed, about 10 play an active role in response. After September 11th, most of the agencies thought communication between them was effective. The results of such research indicate that more frequent exercises and training on existing regulations would probably improve interagency communication. Research in this area will be broadened to address how current systems are working between response activities and mitigation initiatives. It is important to understand how current communications systems can be strengthened and how redundant communications can be used in post-disaster situations.

Coordination for Flight 93 in Pennsylvania[25]

David Hoover conducted research on coordination of the response efforts in Pennsylvania, beginning within 48 hours of Flight 93's crash. The personnel involved in response efforts were interviewed. On-site observations, triangulation, and focused interviews were also used, and a number of local documents examined. This analysis showed that emergency plans and interagency exercises make a difference in the ease of operation during disaster response and recovery. The presence of agencies (such as the FBI and the Disaster Mortuary Response Team (D-MORT)) that were not familiar with the local plans and procedures caused a few problems that smoothed out as personnel continued to work together and became familiar with the reasons behind the activities. The 13-county agreement in western Pennsylvania for emergency response was essential during recovery as it enabled the final sweep of the debris field once the FBI had completed its investigation and released the site.

Impacts and Ramifications of September 11th for Federal Emergency Management [26]

Understanding the impacts and ramifications of September 11th on federal emergency management was another research focus, this one undertaken by Claire B. Rubin. Secondary sources of information, and after-action reports were used, as well as the conceptual framework of the Disaster Time Line. Legislation, regulation, executive orders, response plans, and organizational changes were analyzed. The main finding was that it is not possible to overstate the dramatic changes in political culture, attitudes, and philosophy of the federal government with regard to emergency management resulting from September 11th. There was a major sea change for the Bush Administration and for the government at every level, and notable changes in the willingness to address terrorism. Between September 11, 2001 and the end of 2001, several U.S. General Accounting Office reports, three new laws, three executive orders, and two national security directives were issued.

Victim Information Management and Victim Assistance[27]

David Simpson and Steven Stehr found that the management of disaster victims included a search and rescue phase, the retrieval of bodies and human remains, victim identification, and the disposition of bodies. A research question in this area was how the specific characteristics of the World Trade Center collapse altered the task of victim management. This event had several unusual characteristics. For example, the nature of the site (simultaneously a crime scene and a mass grave) pitted victim retrieval against debris removal. The nature and timing of the attack (against iconic symbols of capitalism) led to fear of other attacks. The scope and intensity of the destruction was another defining characteristic.

Additional research areas were the organization, coordination, monitoring, and evaluation of victim assistance programs, the definition of victims, the provision of resources and access to programs, and the facilitation of paperwork. Initial recommendations that emerged from this area of work was the need to have a victim identification and information clearinghouse on the internet or in another medium, and to have a centralized donation and distribution monitoring system.

Response and Resilience in the World Trade Center Attack[28]

Kathleen Tierney described her project, which focused on the multi-organizational response that was undertaken by New York City agencies after the attack on the World Trade Center. Data for the study were collected through direct observation at the city's Pier 92 Emergency Operations Center (EOC) and at other sites at which decisions were made and response activities carried out after the attacks, including command posts, staging areas, and the Ground Zero site. Preliminary findings indicate that New York City responded in a resilient fashion to a near-catastrophic disaster that far exceeded the scope of prior planning. The city was creative in its use of resources to offset the loss of its state-of-the art EOC, which had been located at 7 World Trade Center. That structure had to be evacuated at the height of the emergency and later collapsed due to fire on the afternoon of September 11th.

The reconstituted EOC at Pier 92, which became the coordinating center for the emergency response, was significantly larger than the EOC the city had lost. The newly-improvised facility, with nearly 250 computer workstations, was able to accommodate representatives from hundreds of organizations and provided a wide array of support functions, including functions not envisioned in earlier planning. At the same time, the spatial arrangements at Pier 92 mirrored those of the original EOC, which facilitated interorganizational interactions and provided needed continuity for the overall emergency response effort.

Behavioral Responses to September 11th

A number of research projects focused on the response of different groups of people to the September 11th disaster. Besides transportation users, whose behavioral changes were described above, other research examined the response of the general population, and of specific groups such as volunteers, advocacy organizations, students, and faith-based groups.

Responses to the World Trade Center Attacks[29]

One research team worked for four and a half days in the field two weeks after the disaster, interviewing about 40 people, including police, fire fighters, military/national guard, religious leaders, Ground Zero workers, New York City teachers, and New York City Board of Education members. The last two groups were the main focus of the study. As explained by researcher Paul O'Brien, the project used a theoretical model of risk communication to test the hypothesis that, given the nature and magnitude of the event, certain differences could be expected from previous literature on response to disasters.

The early results suggested that this event had a massive impact on the community and the nation, that the threat was ongoing, and that the long-term national impact will be substantial in politics and other fields. Among students, the long-term impacts are also substantial: a major increase was expected in the dropout rate in New York City's high schools. To anticipate events such as this, emergency plans need to be revised. New scripts for public officials are also needed. For instance, it is important to address the question of whether the country is at war during such an emergency or whether people should carry on with their lives.

Community Response to Attacks—Spontaneous Volunteers[30]

One of the most visible behavioral responses in the New York City community after the attacks of September 11th was volunteering. A project described by Seana Lowe and Jenna Peck studied the volunteer community by interviewing 23 people, 20 spontaneous volunteers and three professional volunteers. They were asked how they heard of the attacks, what their feelings were, and how they knew what to do. The responses suggest that people were motivated by a compulsion to react. A commonly cited barrier to volunteering was the overwhelming number of volunteers. There was a sense of increased solidarity. Overall, people were extremely impressed by the emergency response.

Advocacy Organization Response to a Suddenly Imposed National Disaster[31]

One lesson confirmed by the September 11th disaster was that in the aftermath of this type of event groups that do not usually work together begin to do so, according to an investigation by Bob Edwards and Patrick Gillham. This was also observed in Mexico City after the most recent earthquake and in North Carolina after the floods. After September 11th a number of advocacy organizations responded by working together, which presents an interesting research area in behavioral science and organization theory.

Ethnic Issues on University Campuses after an Act of Terrorism: Arab and Muslim Student Response[32]

Another research area in the field of behavioral responses to urban disaster is the response of specific ethnic and religious groups. Researcher Lori Peek conducted interviews with Arab and Muslim students in a number of New York City schools: New York University, Baruch College, Brooklyn College, City College of New York, Hunter College, Columbia University, and Queens College. These interviews were completed in late September and early October, 2001. Responses varied by gender and levels of ethnic and religious identification. One of the outcomes observed after this event was that there was a "racialization" of Muslims.

In December 2001, the researcher met with students in Colorado and with additional students in New York City. The total number of students interviewed was 126. The ongoing changes in behavior observed were more dramatic during the second round of interviews. Additional work with a more diverse sample population was considered necessary, including interviews with Arabs and Muslims of different ages and different education levels.

Psychological Reactions among Students after September 11th[33]

David Sattler examined the psychological reactions to September 11th of over 1,280 college students in New York, South Carolina, Colorado, and Washington, three weeks after the attacks. Between half and three-quarters of the students interviewed expressed concerns about future attacks such as "afraid family member might lose his/her life or be seriously injured in future terrorist attack;" "afraid I might lose my life or be seriously injured in future terrorist attack;" or "I have a family member or friend who will be at increased risk due to U.S. response to the event." About one-tenth of the students reported difficulty sleeping, avoiding things that remind them of the attacks, anxiety, nightmares, emotional numbness, feeling irritable, and difficulty remembering important things about the situation. More students in the East reported these symptoms than in the West. On the other hand, almost three-quarters of the students reported feeling patriotic, setting new priorities about what is important in their lives, having new respect for people in their communities, appreciation of each day, feeling closer to family members, and discovering that they are stronger than they thought they were. A study of the Arab and Muslim population conducted by Lori Peek showed different results, indicating that they are not feeling resilient or patriotic.

Faith Community Responses to New York City Terrorist Attacks[34]

There is little research describing the response and recovery activities of faith-based organizations after disasters. Jeannette Sutton conducted research through which she interviewed members of several New York City interfaith groups, Presbyterian congregations, the Church World Service, and faith-based groups affiliated with the American Red Cross, in an attempt to understand the ways in which those organizations rose to new challenges after the disaster.

Future Research Issues and Cross-cutting Themes

At the conclusion of the workshop, a group discussion identified the research themes listed below. These themes are a starting point for further discussion about research needs identified as a result of the September 11th disaster. A message board was set up on the ICIS website (http://www.nyu.edu/icis/Recovery) called "Online Discussion Forum" for the purpose of posting additional suggestions.[35]

Social and Human Behavioral Dimensions

Resiliency, Vulnerability and Criticality of Human Systems

The events of September 11th provided an important context for developing a better understanding of sources of psychological, social, and economic vulnerability, and for exploring ways in which human systems achieve resilience in the face of major disasters. Topics for future research are

- Methods, models, etc. to assess both vulnerability and resiliency of social, political, and economic systems across different units of analysis (e.g., individuals, organizations, institutions in both the public and private sector, as well as non-governmental organizations), geographic scales, and phases of emergency management (i.e., preparedness, response, recovery, and mitigation);
- Assessment of direct, (psychological, social, economic), indirect, and ripple effects resulting from September 11th; and
- Risk factors affecting both impacts and outcomes.

Relationships and Connections between Human and Physical Systems

Research is needed to identify ways in which the built environment and human and organizational behavior interact to either amplify or reduce vulnerability. Topics for study include

- Models, methods, and data focusing on the interface between human and physical (engineered) systems, and in particular ways in which these systems can be better integrated. Examples include building designs and emergency plans to enhance life safety by protecting building occupants and facilitating emergency egress; and
- Risk communication, pre-event planning, and post-event response management to protect lives and property and encourage appropriate self-protective behavior.

Institutional Arrangements

Additional research is needed to address institutional, multi-organizational, and organizational dimensions of pre-event mitigation and planning and post-event response and recovery. Research focusing on the following areas is needed:

- Capability and adaptability of institutions (e.g., governmental and private-sector organizations and entities responsible for infrastructure maintenance) to deal with vulnerability both before and after a disaster;
- Interorganizational and intergovernmental relations, including dynamics of multi-agency decision making and challenges associated with horizontal (among organizations) and vertical (among different governmental levels) integration in major crises;
- Communications and information sharing among individuals, groups, and organizations, especially with respect to the various phases of the emergency management cycle (e.g., preparedness, response, recovery, and mitigation); and
- Social, political, legal, administrative, and other factors that influence institutional behavior and response in large-scale and near-catastrophic events.

Decision Making and Risk

Additional research is needed to improve decision making at different units of analysis. Topics for further research include

- Models and approaches to characterize tradeoffs and decision processes employed by individuals, organizations, and institutions across the emergency management cycle; and
- Decision processes at various levels of analysis across the entire hazards/emergency management field and those that provide linkages among the various stages of the cycle.

Structures and Physical Systems

Analytical Models/Simulation of Performance

This capability has been developed in other areas and can be applied to structures. Data from the World Trade Center collapse is needed to validate such models and simulations. The design and operation should be considered under normal and extreme events. Data from other buildings and cases should also be included.

Analytical Models/Simulation of Building Systems

This area refers to the electrical and mechanical aspects of buildings. Examples include temperature, air flow, and other aspects. Data from the World Trade Center disaster is needed to validate these models and simulations. Design and operation under normal and extreme events should be included.

Analytical Models/Simulation of Emergency Management and Human Response

Such tools can be used in planning and execution. Data from the World Trade Center disaster should be used to validate these models and simulations.

Analytical Models of Information Flows and Information Sharing

This research topic consists of looking at what was done in terms of data sharing and what could be done better in the future. An area of research within this topic is the availability and incentives for sharing information, and being able to demonstrate the consequences of lack of sharing. How access to information can be preserved while respecting security needs is a key challenge.

Debris Field and Collateral Damage

This research area addresses questions related to where the collapsed pieces are likely to go and what the structure of the collapsed material is likely to be. The area of analysis includes both the surface and subsurface, and also includes infrastructure.

Structure of Collapsed Buildings

This refers to three areas: safety and removal; prediction of void spaces; and strategies for search and rescue.

Environmental Consequences

This area includes, but is not limited to airborne/plume models; waterborne and land-based pollution; evolution of source over time; and model validation for the World Trade Center and other crises in urban terrains.

Intelligent Buildings and Bridges

This research addresses the role of advanced technologies on intelligent structures/buildings and their future performance goals.

Distributed Networks

Given New York City's unique energy network, an important research question is what a similar disaster would do in a setting with a different energy network configuration. This area also refers to strategies for resilient networks and complex adaptive systems, such as energy, communications, water, and others. The World Trade Center disaster and other cases can be used to understand what worked and why.

Tools for Making Risk-informed Decisions

This includes databases of networks, models and processes. The main research question is how models of structures, networks, and processes can be integrated into risk models and risk management.

Fragility Curves for Organization Collapse

This area of research refers to the application of models from physical systems to organizations. An example could be how organizations perform under different levels of stress.

Interdependencies among Infrastructure Systems

At the time of the September 11th attacks, systems that were functionally and structurally interdependent may have magnified the impact on any given system. Research on infrastructure interdependencies needs to address the ramifications on other systems of one system's failure.

Cost/Consequence Models

Issues related to costs and benefits should be considered for normal and extreme events, as well as for response efforts.

Cross-Cutting Issues

Many research needs span both engineering and the social sciences. These common areas include the need for

- Improved theories, models, methods, and analytical tools, including tools that are capable of integrating data both spatially and temporally;
- Strategies to ensure maximum data availability, access, and sharing;
- Research focusing on documenting and analyzing both successes and failures in engineered and human systems (e.g., robust and redundant structures and systems, successful organizational coping and adaptation in crises);
- Research to better understand similarities and dissimilarities among varied disaster agents— natural, technological, and terrorism-related disasters; and
- Studies that address the needs of a wide range of users and target audiences (e.g., organizations charged with responsibility for managing response, recovery and reconstruction activities).

Notes

1. Based on a presentation at the workshop by Anthony Townsend, Lecturer, Robert F. Wagner Graduate School of Public Service and Associate Research Scientist, Taub Urban Research Center, New York University.

2. Based on notes from presentations at the workshop by Abolhassan Astaneh-Asl, Professor of Civil and Environmental Engineering at the University of California at Berkeley; W. Gene Corley, American Society of Civil Engineers; and Michael Bruneau, Professor of Civil, Structural and Environmental Engineering and Deputy Director of the Multidisciplinary Center for Earthquake Engineering at the University of Buffalo, State University of New York (summary not reviewed by presenters).

3. Based on a presentation by Frederick W. Mowrer, Associate Professor, Department of Fire Protection Engineering at the University of Maryland.

4. Based on a presentation by W. Gene Corley, American Society of Civil Engineers.

5. Based on a presentation by Thomas O'Rourke, Thomas R. Briggs Professor of Engineering, Cornell University.

6. Based on a presentation by Cruz Russell, Director of Policy and Planning, Port Authority of New York & New Jersey.

7. Based on presentations by Joe Englot, Chief Structural Engineer, Port Authority of New York & New Jersey; and Joseph N. Siano, Vice President/Program Executive, System Expansion, Capital Program Management, New York City Transit.

8. Based on a presentation by David Woloch, Chief of Staff, New York Department of Transportation.

9. Based on a presentation by José Holguín-Veras, Professor of Civil Engineering at Rensselaer Polytechnic Institute.

10. Based on a presentation by Elie Chebli, Manager of Network Design, Consolidated Edison.

11. Based on a presentation by Elie Chebli, Manager of Network Design, Consolidated Edison.

12. Based on a presentation by Anthony Townsend, Lecturer, Robert F. Wagner Graduate School of Public Service, New York University.

13. Based on a presentation by Diana Chapin, New York City Department of Environmental Protection.

14. Based on presentations by Diana Chapin, New York City Department of Environmental Protection, and David Lipsky, New York City Department of Environmental Protection.

15. Based on a presentation by William Wallace, Professor and Research Director, Center for Infrastructure and Transportation Studies, Rensselaer Polytechnic Institute.

16. Based on a presentation by J. David Frost, Professor, School of Civil and Environmental Engineering and Director of the Regional Engineering Program, Georgia Institute of Technology.

17. Based on a presentation by Susan L. Cutter, Carolina Distinguished Professor of Geography and Director of the Hazard Research Lab, University of South Carolina.

18. Based on a presentation by Christine Rodrigue, Professor and Chair, Department of Geography, California State University.

19. Based on a presentation by Michael Berkowitz and Mary Ann Marrocolo, New York City Office of Emergency Management.

20. Based on notes from a presentation by Randolph Langenbach, Federal Emergency Management Agency (summary not reviewed by presenter).

21. Based on a presentation by S. Shyam Sunder, National Institute of Standards and Technology.

22. Based on notes from a presentation by John Harrald, Director of the Institute for Crisis, Disaster, and Risk Management and Professor of Engineering Management in the School of Engineering and Applied Science at George Washington University (summary not reviewed by presenter).

23. Based on notes from a presentation by Richard T. Weber, Emergency Administration and Planning Adjunct Faculty and Professional Development Coordinator at the Center for Public Management in the Development of Public Administration at the University of North Texas (summary not reviewed by presenter).

24. Based on a presentation by Robert Parker, Managing Director of the Community Service Center at the University of Oregon.

25. Based on a presentation by David H. Hoover, Professor of Emergency Management and Fire Protection Technology at the University of Akron.

26. Based on a presentation by Claire B. Rubin, independent consultant at Claire B. Rubin & Associates.

27. Based on a presentation by Dave Simpson, faculty member in the Department of Urban and Public Affairs and Associate Director of the Center for Hazards Research and Policy Department at the University of Louisville; and Steven Stehr, Associate Professor in the Department of Political Science and Criminal Justice at Washington State University.

28. Based on a presentation by Kathleen Tierney, Professor of Sociology and Director of the Disaster Research Center at the University of Delaware.

29. Based on a presentation by Paul W. O'Brien, faculty member of the Department of Sociology and Criminal Justice of California State University.

30. Based on a presentation by Seana Lowe, Program Director of the International and National Voluntary Service Training Program at the University of Colorado at Boulder; and Jenna Peck, Research Assistant at the Natural Hazards Research and Applications Information Center at the University of Colorado at Boulder.

31. Based on a presentation by Bob Edwards, Associate Professor and Graduate Director of the Department of Sociology at East Carolina University; and Patrick Gillham, doctoral candidate in the Department of Sociology at the University of Colorado at Boulder.

32. Based on a presentation by Lori Peek, doctoral candidate in the Department of Sociology, University of Colorado at Boulder.

33. Based on a presentation by David Sattler, Professor of Psychology, Western Washington University.

34. Based on a presentation by Jeannette Sutton, doctoral candidate at the Department of Sociology, University of Colorado at Boulder.

35. The moderators of the two breakout sessions were Priscilla Nelson, Director, Division of Civil and Mechanical Systems at the National Science Foundation and Rae Zimmerman, Director of the Institute for Civil Infrastructure Systems at New York University.

References

Extreme Events Mitigation Task Force. 2002. “A Briefing on the World Trade Center Attacks.” *Fire Protection Engineering* (13): 46–52.

U.S. Environmental Protection Agency. 2000. “The Emergency Planning and Community Right-to-Know Act Factsheet.” EPA 550-F-00-004. Washington, D.C. EPA. http://yosemite.epa.gov/oswer/ceppoweb.nsf/7b422e07538ad30585256bde007a7bf7/85256b9f0072443385256c2c0057ce03/$FILE/epcra.pdf.

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