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Managing Pedestrians During Evacuation of Metropolitan Areas

U.S. Department of Transportation
Federal Highway Administration

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MANAGING PEDESTRIANS DURING EVACUATION OF METROPOLITAN AREAS

Publication No. FHWA-HOP-07-066 **March 2007**

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U.S. Department of Transportation
Federal Highway Administration

March 2007

Dear Colleague,

Emergencies can occur at any time, any place. We all need to be prepared to take immediate actions to move out of harm's way quickly from wherever we are at the time. The September 11(or 9/11), 2001, attacks on the high-profile workplaces of the World Trade Center (WTC) in New York City and the Pentagon in the Washington, D.C. area, made real the impact of an unexpected, or "no-notice," event in a metropolitan setting. News coverage of the events of 9/11 showed thousands of people leaving the area of the WTC on foot. The evacuation from the borough of Manhattan included not only the typical traffic congestion expected in an evacuation in the United States, but thousands of pedestrians moving along with, or among, the vehicles. However, unexpected emergencies causing people to evacuate an area can result from transportation accidents, hazardous materials releases, earthquakes, flash flooding and other natural and man-made causes.

When a large-scale, damaging event has occurred or the imminent threat of one has become known, transportation agencies, working with public safety and emergency management officials, focus on two traditional, principal objectives:

- Minimize the time it takes to get an adequate force of emergency responders to the scene where they can help victims, provide assessments, and control access.

- Maximize the proportion of the population moved away from the hazardous area without being subjected to other risks (e.g., traffic accidents; prolonged exposure to the danger).

Evidence that large numbers of pedestrians may be part of an evacuation raised questions within the Federal Highway Administration (FHWA) about what actions are needed to manage pedestrian traffic during metropolitan evacuations and what FHWA can contribute in this area to ensure safe and effective movement of pedestrians while minimizing their impact on vehicular movement. This study resulted from these inquiries.

This document is one of a series of publications that FHWA has been producing to aid local, State and Federal authorities in designing evacuation and other types of emergency transportation operations plans. While transportation authorities have responsibility for developing transportation-specific plans, we expect that they are being done in the construct of the community's or State's emergency management planning efforts. We encourage our transportation partners to share information in this and other ETO guides with their emergency managers and first responders and to watch for new publications in the Emergency Transportation Operations series, found on http://www.ops.fhwa.dot.gov/opssecurity or the ETO page on https://www.dhs.llis.gov.

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16. Abstract

The September 11(or 9/11), 2001, attacks on the high-profile workplaces of the World Trade Center (WTC) in New York City and the Pentagon in the Washington, D.C. area, made real the impact of an unexpected, or "no-notice," event in a metropolitan setting. The news coverage of the events of 9/11 showed thousands of people leaving the area of the WTC on foot. The evacuation from the borough of Manhattan included not only the typical traffic congestion expected in an evacuation in the United States, but thousands of pedestrians moving along with, or among, the vehicles.

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EXECUTIVE SUMMARY

Transportation Agency Interest in Pedestrian Evacuation

The September 11, 2001, (or 9/11) attacks on the high-profile workplaces of the World Trade Center (WTC) in New York City and the Pentagon in the Washington, D.C. area, made real the impact of an unexpected, or "no-notice," event in a metropolitan setting. The news coverage of the events of 9/11 showed thousands of people leaving the area of the WTC on foot. The evacuation from the borough of Manhattan included not only the typical traffic congestion expected in an evacuation in the United States, but thousands of pedestrians moving along with, or among, the vehicles.

When a large-scale, damaging event has occurred or the imminent threat of one has become known, transportation agencies working with public safety officials have traditionally had two principal objectives:

- Minimize the time it takes to get an adequate force of emergency responders to the scene where they can help victims, provide assessments, and control access.
- Maximize the proportion of the population moved away from the hazardous area without being subjected to other risks (e.g., traffic crashes, prolonged exposure to the danger).

Evidence that large numbers of pedestrians may be part of an evacuation raised questions within the Federal Highway Administration (FHWA) about what actions are needed to manage pedestrian traffic during metropolitan evacuations and what FHWA can contribute in this area to ensure safe and effective movement of pedestrians while minimizing their impact on vehicular movement.

Scope of the Research

The term "no-notice metropolitan evacuation" here refers to an emergency evacuation taken as a protective action that is implemented for a portion of a densely built-up downtown area in a large city in the United States. The basic situation assumed for the discussion of the issues is the following:

- The triggering event will occur without warning (e.g.: terrorist attack, explosion, or toxic release);
- The scope of the event will be such that an emergency evacuation activity will be critical for a portion of the metropolitan area;
- Emergency response actions will occur to mitigate the injury and damage from the destructive or threatening event even as the evacuation is taking place;
- The evacuation is expected to be temporary for those parts of the area that were not badly damaged or contaminated.

The term “pedestrian evacuation” generally refers to masses of people who leave a suddenly dangerous area in order to reach a safer place and do so on foot. For pedestrian evacuation to be of concern to transportation agencies, it entails the combination of masses of people on foot along with the corresponding congestion of the evacuation of others in private vehicles, always or at times moving along the same routes. Examination of the 9/11 situations in New York City and Washington, D.C., also brings out the need to consider the situation of large numbers of people who are initially on foot but have chosen their route because it takes them to a point for accessing mass transit that can take them out of the city. These two examples also suggest that when a downtown business district is the source of the evacuation streams, a large proportion of the evacuees will have as their intended destination their residence, even if it is far beyond the distance they need to travel to be in a safe location.

The reader should consider this report as an initial and cursory effort to identify what is already known about managing pedestrian traffic in U.S. metropolitan evacuations. The research tapped a large variety of information sources for insights. These included published studies representing a variety of disciplines (Chapter 2), telephone interviews with practitioners in cities representing examples of emergency evacuation or evacuation planning for the city (Chapter 3), and a discussion of variables and issues with a multi-disciplinary panel of experts convened for a day-long meeting on the topic (Chapter 4). In total, 23 practitioners and other subject matter experts provided information.

The inquiry began with a review of literature that tapped into the topic from several perspectives, including: transportation planning and operations, social and behavioral research on evacuation decision making and behavior, and crowd and pedestrian flow modeling. The research materials included a series of case study reports done for the FHWA to examine transportation operations during catastrophes that included the 9/11 attacks, the Northeast power outage in 2003, and the 1994 Northridge Earthquake in southern California. Several emergency response after-action reports also were found and reviewed, related to the 1993 World Trade Center bombing, the 1995 Oklahoma City federal building bombing, and the 1995 Tokyo subway sarin gas attack.

Findings from the Literature Review

Pedestrian evacuees apparently are a fairly rare phenomenon since car ownership became widespread in the United States. The principal observation from the literature review is that studies of evacuations do not mention pedestrians and no research was found that was focused on the specific topic of pedestrians in U.S. evacuations prior to 9/11. Similarly, no systematic research was found from 9/11 that focused on the unusual phenomenon of large numbers of people who left the city on foot. On the other hand, at least between 1950 and 2000, there have been no sudden and catastrophic events in the larger U.S. cities that would have provided a context for examining pedestrian behavior in no-notice emergency evacuation from a large city.

Practitioner Interviews

The research also identified five cities where emergency evacuations or evacuation planning had taken place and conducted phone interviews with public safety, emergency management, and transportation practitioners in these cities: Washington, DC metropolitan area; Cleveland, Ohio;

San Francisco-Bay Area, California; New York City, New York; and Seattle, Washington. Some selected points of importance for practitioners are the following:

Observations from Washington, D.C., practitioner interviews:

- *Selected points important for practitioners:* The evacuation on 9/11 was spontaneous rather than recommended, causing the traffic control measures to prevent gridlocked traffic to lag behind the initial stages of the evacuation. The large numbers of people leaving office buildings at approximately the same time created even larger crowds on the sidewalks and around mass transit loading areas than does an end-of-day commute. The sudden deployment of security barriers around government facilities created unfamiliar detours for both drivers and pedestrians. Since 9/11, traffic cameras have become more common along major routes, and can be of considerable value in the event of a future evacuation. The transportation agency also intends to continue to deploy "spotters" to watch the evacuation traffic at key points in order to be able to resolve traffic conflicts or delays before they worsen. It is critical for transportation agencies to work closely with the mass media to ensure that no misinformation gets reported about the status of the mass transit system. Mass transit, especially rail service, can be an important mode for use by evacuees because it is not affected by traffic congestion.

Observations from Cleveland practitioner interviews:

- *Selected points important for practitioners:* The evacuation of just a few downtown buildings in the face of a general threat (as happened in Cleveland on 9/11) is likely to prompt evacuation of the entire downtown area so it is important for responders to be prepared to manage it. When the development of a downtown evacuation plan was undertaken shortly after 9/11, the mayor involved the downtown building owners and managers groups as well as public safety and other government agencies. This helps to spread the education efforts among many participants about the evacuation plan. The normal contingency plans that the transit authority has for quickly creating "bus bridges" if some portion of the rail system becomes inoperable are easy to activate should they be needed to effect some part of a city evacuation. When Cleveland was affected by the Northeast blackout of 2003, emergency managers recognized the exodus from downtown as an early commute rather than an evacuation and did not try to invoke the downtown evacuation plan because of its basically different underlying strategy for clearing people from downtown.

Observations from San Francisco Bay practitioner interviews:

- *Selected points important for practitioners:* Experience with portions of highways being suddenly closed due to earthquake damage has made local authorities aware of the situation of drivers suddenly finding themselves in areas they are totally unfamiliar with and in need of staging areas, service, and information. Media convergence on areas with dramatic damage can create a bigger problem for emergency responders than do pedestrian evacuees who are more likely to stay out of the way. Because earthquakes often cause damage to some parts of the transportation infrastructure, the transportation agency is likely to be focused on addressing these problems and not available for

assistance with evacuation streams in other locations. The Oakland Hills fire demonstrated that people accustomed to driving out of their neighborhoods may not think to evacuate on foot along footpaths even when it is evident that driving out will take too long. One law enforcement officer interviewed stated his belief that pedestrians will know what to do and will not need a lot of direct instruction from officials.

Observations from New York City practitioners and other materials:

- *Selected points important for practitioners:* The large number of people who left the downtown area on foot in the face of the attack on and collapse of the World Trade Towers on 9/11 may be a reflection of the fairly large percentage of people who use mass transit to get to work in the business district so are car-less when downtown. The importance of maintaining mass transit as much as possible, and devising means for providing information to people wanting to use mass transit for evacuation, is critical in this situation. The fact that so many of the people who evacuated on foot walked much further than was necessary to be out of any danger suggests that when people evacuate from their offices they are most likely to prefer to get home, even if it is several miles, so response organizations need to prepare to accommodate this behavior and make safer and easier than it would be otherwise. Many ad hoc arrangements were made to accommodate evacuees such as other boats engaging in ferrying people off Manhattan Island, and law enforcement requesting drivers to take as passengers evacuees who might otherwise try to walk across a bridge or through a tunnel to leave Manhattan. Much of what initially looked like pedestrian evacuation was likely to be more multi-modal in that many people walked to where they could get mass transit and completed part of their journey in that manner.

Observations of Variables Affecting Evacuation Management

Using the information from the literature review and the interviews, concepts and practices that would be useful in planning and managing metropolitan evacuations were delineated. Once the various contextual elements of a metropolitan evacuation are established, the planning effort can focus on the combination of response elements that are bested suited to the characteristics of the specific event and the area affected by it. Basic variables that combine to affect the evacuation process, and which form the basis for planning and managing a no-notice urban evacuation, include the following:

- Characteristics and geographic scope of the threat to personal safety;
- Location and number of evacuees;
- Configuration and capacity of evacuation routes and mass transit systems.

This context becomes the basis for:

- Strategic intent of evacuation implementation (e.g., minimize vehicle traffic, maximize evacuees going north, etc.);
- Primary evacuation instructions as formulated by the authorities;
- Available options for communicating instructions to evacuees.

As any transportation or public safety official knows, real events and exercise scenarios seldom fit what would be the "best case" situation for implementing a large scale evacuation from a city center. There obviously can be multiple combinations of variables related to the type of event, characteristic and current conditions of the area, transportation and routing alternatives, whether evacuees are leaving home or going home, and the degree of preparedness and cooperation among the agencies involved in facilitating the evacuation.

As another effort to gather ideas, a multi-disciplinary group of subject matter experts was convened to address issues related to pedestrian evacuation from various perspectives. The panel participants included practitioners and subject matter experts in firefighting and incident command, evacuation planning, public safety and law enforcement, traffic operations, modeling of pedestrian movement, and social science research on evacuation and disaster response. (It should be noted that invited transit agency representatives were unable to attend.)

A major recurring theme was that best practice for managing pedestrian evacuees lies with the application of best practice in overall emergency preparedness and response. For most participants in the discussion the emergence of a large contingent of evacuees on foot was viewed as an element that may or may not occur in conjunction with an urban evacuation. The most important factor for effective management of pedestrian evacuation as a variable related to context and situation is that all relevant agencies have, first, a shared understanding of the concept of operations for the jurisdiction's agencies, and second, established working relationships with other agencies either during actual response activities or preparedness activities such as evacuation planning and emergency exercises. At the same time, another important theme was that there may be conditions under which a largely pedestrian evacuation might be a preferred strategy for getting people moved a short distance to safety, with the associated issue of whether evacuees could be expected to accept instructions to abandon familiar transportation modes or walking routes.

The ability to do this would depend on a shared understanding of applying decision criteria in a timely manner.

Other themes and issues raised by the panel were:

- Preparation for special considerations related to pedestrian evacuation may be particularly important in cities with large numbers of tourists and high commuter use of mass transit, because many people will be unfamiliar with routes and landmark facilities named in evacuation messages.

- Interagency planning for how best to provide clear and consistent information to pedestrians that enables them to make quick decisions about evacuation and route selection can help to reduce the amount of responder attention needed to manage pedestrian evacuation.

- In cities where Intelligent Transportation System (ITS) assets are well developed, the transportation agency will have some of the best information and the broadest overview of the traffic and pedestrian flow, making it imperative that the transportation agency participates in emergency management functions and not simply in a support role.

Chapter 5 presents conceptual approaches for transportation and emergency planners to consider for managing and accommodating pedestrian evacuation. These are a reflection of solutions implemented by New York City to keep evacuating pedestrians, vehicles, and emergency vehicles separated and of evacuation concepts reflected in two downtown evacuation plans identified during the project. These plans included public education about how people evacuating on foot would be accommodated. Because of the location of the main business district of New York City being on the island borough of Manhattan, it is possible for emergency response planners to assume that evacuating vehicles and pedestrians will converge at the few transportation facilities for leaving the island, and so can focus attention on how to balance mobility and safety at those points. The two downtown evacuation plans discussed by the panel have not as yet had to be implemented, but are designed around a basic strategic intent of getting much of the downtown population to immediately move on foot directly away from the danger area with the knowledge that there are several pre-determined locations where evacuation buses will be staged.

In order to outline generic options for managing or accommodating pedestrian evacuees, it is necessary to hold constant the underlying scenario of the event. The following evacuation planning concepts suggested here extend beyond the familiar one of evacuees all driving or riding in private vehicles. For the sake of a simple presentation, these are predicated on the existence of the basic, best case scenario of an impact that has not created an airborne hazard, in a downtown district that is mostly office buildings, daytime and good weather conditions, and operable mass transit options. These are referred to as conceptual approaches to indicate that they are presented as pure types, without an attempt to address actual variations in the context or the nature of the agent prompting the evacuation.

Three approaches assume there will be appreciable numbers of pedestrians among the population making a temporary evacuation from an area because of an unanticipated and major impact in the densely developed downtown area of a large city. The reader is cautioned that this basically is just an assumption, there having been too few such events in large U.S. cities to know if the scenes from the 9/11 attacks in New York City and Washington, D.C., are likely for those cities only because of some particular characteristics or the particular 9/11 events, or if they are likely to occur in other large U.S. cities.

The three general modes available to individuals whether they are commuting from home to work or going about a city for errands or social engagements are: driving a private vehicle, riding in a private vehicle or public transit, or walking. People who are car-less in a large city normally have several options for making trips within the city or back and forth between home and work. All of these modes are suitable to situations requiring evacuation of a portion of a city. In densely developed urban areas evacuation in one's private vehicle may not be the most effective for making a rapid evacuation. Under certain circumstances, greater use of other modes may be more suitable for achieving a balance of rapidity and safety for the largest number of people.

The three approaches share a common objective: to ensure the safety and mobility of pedestrians while minimizing the likelihood that they may contribute to evacuation traffic congestion. Crowd and traffic management techniques can be used to separate vehicle and pedestrian streams, or, taking a different angle, the pedestrian stream can be reduced as the evacuation progresses.

Conceptual Approaches for Managing Pedestrian Evacuation in Metropolitan Areas, from the Perspective of Emergency Management

Conceptual Approach	Strategic Objectives of the Evacuation
1. Designate and manage separate evacuation corridors for outbound vehicles and for pedestrians.	• Minimize the need for complex logistical activities on the part of the transportation managers. • Minimize the number of points where pedestrians and vehicles are in close proximity.
2. Provide dedicated evacuation transit hubs at the outer perimeter of the evacuation zone to which evacuees can walk.	• Minimize the distance that evacuees are on foot and exposed to certain hazards. • Provide a transit option for evacuees who began evacuation on foot due to lack of other options. • Avoid putting disruptive activities like bus loading in and around the command and operations area. • Increase the likelihood of having an appropriate space for gathering evacuees and loading buses. • Avoid the need for extremely complex logistical activities by transit services.
3. Provide "bus bridges" from where large numbers of people are emerging from the buildings to designated points at the edge of the area being evacuated, where people disembark and begin walking to their destination or find other scheduled mass transit.	• Reduce the magnitude of the evacuation stream of evacuees on foot in the area with the greatest potential for impeding vehicles. • Take the buses into the evacuation zone to provide greater visibility of the option for being evacuated by bus. • Give car-less evacuees with limiting conditions an option besides walking. • Provide a safe environment for evacuees when time or weather conditions are inimical for walking. • By using a short route loop, reduce the time it takes each bus to return to the staging area for another load of evacuees.

The other three theoretically logical approaches evacuation planners might consider for reducing or eliminating risks created by evacuation streams including both vehicles and pedestrians are the following:

- Prohibit or minimize evacuation on foot, other than for moving on foot to transit options or private vehicles, which is the form of evacuation that seems to emerge naturally in the United States, given generally low density towns and cities, and high levels of car ownership.

- Prohibit or minimize the choice of evacuation by vehicle, as a way to eliminate evacuation delays caused by the extreme traffic congestion due to the sudden increase of vehicles on the streets within a very short time period, in particular in high density urban places. For this to happen, authorities would have to prohibit people from accessing private vehicles parked in the area.

- Prohibit or minimize evacuation, which is the option of sheltering-in-place that is adequate as protection under some types of circumstances or, even if imperfect for complete safety, the best option when imminent danger creates a greater risk for those who are on the streets rather than in buildings at the moment.

The first of the three is the most likely to be feasible to implement because it is already a behavior that typically emerges in the United States when evacuation is recommended by authorities. Evacuating in one's private vehicle allows the evacuees some discretion in deciding how far to go and permits the evacuee to keep at least this one valuable possession at hand. The latter two call for authorities to recommend and expect that individuals will follow instruction that runs counter to the typical social behavior observed by disaster researchers.

Findings from many decades of disaster research lead social scientists to be skeptical of the likely effectiveness of emergency planning based on the assumption that the population will do what makes the most sense to planners and responders. Behavioral research suggests that emergency planning instead needs to acknowledge what makes the most sense to people whose first concern will be for assuring the safety of other family members or friends even at the risk of delaying appropriate protective action for oneself. However, the social scientists are also quick to observe that, in actuality, there is little empirical evidence at this time for knowing if what is known about evacuation behavior in smaller cities will apply in concentrated metropolitan areas. The most commonly observed response and evacuation behavior has been in response to the traditionally structured environment of smaller cities. Persons living in high density urban environments and more used to transportation alternatives can be expected to collectively adjust their behavior to that context. The unanticipated emergence of pedestrian evacuees in New York City and Washington, D.C., in the face of the 9/11 situation provides some evidence that there will be differences in future events in similar settings, because of the 9/11 experience. Not only was the option of evacuating on foot "publicized" through media accounts as an option during urban evacuation events, but the delays drivers experienced because of the initially gridlocked traffic may result in more urban evacuees being willing to try other options in the future. Circumstances that differ in many high density downtown areas, compared to smaller cities, include better walking facilities, more mass transit options, and a greater likelihood that a large proportion of the evacuees are headed home, not leaving home. Evacuees headed home will have a route in mind, because of this preferred destination.

Research Needs

Up to this time, evacuations from large, highly concentrated U.S. cities similar to New York City, Chicago, or San Francisco are virtually lacking to provide sufficient information upon which to base expectations. Systematic study of large-scale pedestrian evacuation in U.S. cities still is needed to better understand how pedestrian evacuees react to various types of settings, situations, and instructions. At the highest level of generality, previous research indicates they

will behave rationally; what is not yet systematically documented is the specific adaptive and problem-focused evacuation behavior from the point of view of urban occupants.

The research for this report was conducted prior to Hurricanes Katrina and Rita in September 2005. The evacuation of the New Orleans Metropolitan Area in response to the several-day advance warning about the approaching hurricanes followed the typical pattern for hurricane evacuations. Approximately 75% of the occupants evacuated, most driving or sharing private vehicles, during the warning period that preceded the hurricane impact. Almost half of the 25% who did not evacuate thought it would be safe to stay. The unanticipated flooding from the levy breaches necessitated rescue of many of those who had not evacuated.

Transportation managers and researchers need to be prepared to conduct studies following the next case of a major metropolitan evacuation from a no-notice event. FHWA sponsored relatively detailed case studies of the 2001 and 2003 evacuations from New York City and the 2001 evacuation from Washington, D.C., but the objective of the case studies was to determine the disruptions to transportation activities and adjustments made by the transportation agencies. Consequently, the large number of people evacuating on foot was more a finding than a focus of the inquiries.

At the moment of this report, there are two major opportunities for gathering more systematic detail about urban evacuations involving pedestrian evacuees: the last case of a large scale pedestrian evacuation and the next one. The most recent cases would be that of people leaving Lower Manhattan after it became evident that two airliners hitting the World Trade Center towers was not an accident, and the government and other office workers spontaneously leaving downtown Washington, D.C., as news of the attacks reached them. Various types of research were found in relation to New York City, but none was identified that provided an overview of the decision points of the pedestrian evacuees or the interactions between pedestrians and the agency officials with roles related to facilitating the temporary evacuations. Now that issues have been raised about pedestrian evacuation, preparations should be made for research on the next case as well. General areas of recommended research about the management and accommodation of pedestrians from these two past cases and in the next case of no-notice urban evacuation are the following:

- Surveys with samples of people who work in office buildings in the downtown area to obtain more detailed information about their evacuation decision, the transportation mode (including walking) that they selected, what information they used to make these decisions, what other information they wish they had had, and if they intend to make different decisions in the event of another evacuation situation. This information can be compared to findings from earlier research on evacuations from cities and towns of lesser population density to determine similarities and differences.

- Interviews with key staff from relevant agencies that can be used to triangulate the observations of officials (e.g., law enforcement, traffic control, or transit personnel) who were located in different parts of the city and operations centers when the evacuation began and as it progressed. This could help to pinpoint if, how and where pedestrians, private vehicle traffic, and emergency vehicle traffic were intermixed and how situations of traffic and pedestrian congestion that emerged were resolved. Findings from such

research would help identify the extent of such congestion, factors related to its existence, the ways in which safety and mobility were affected, what might be effective approaches for mitigating such congestion if it presents an actual problem, and what specific messages for evacuees were provided through what means.

- Compilation of photographic records (both still-images and video captured by private, mass media, and even surveillance cameras) identified with respect to specific location. These could provide important details about the routes and behaviors of the pedestrian evacuees and of interactions between pedestrians and officials as the basis for providing scenarios for consideration by the city's evacuation planners. Such otherwise quickly disappearing "data sets" might exist with the mass media, private citizens' video recordings, traffic and security surveillance cameras at intersections and on buildings, ATMs, fortuitously-timed satellite photographs, and so forth. This technique could provide a wide scale and graphic overview of a phenomenon that is difficult to make sense of when viewed from only one or two locations. This information could be used by evacuation planners to consider appropriate measures for facilitating and managing both traffic and pedestrians.

If transportation and emergency management agencies view as high priority the possession of better information on which to base planning assumptions about evacuations with large numbers of people on foot as well as in vehicles, it is important that the decision to collect this information be made in advance of the next event. Timely post-disaster research calls for consideration of how to make resources immediately available for data collection.

Summary and Conclusion

In summary, the main intent of this research was to try to identify practices or ideas that transportation managers and public safety agencies were planning or maybe had actually used, to ensure that people evacuating on foot and people evacuating in vehicles did not hamper each other's mobility in relation to a preferred destination. Public safety and emergency response practitioners expressed concern that they had not given adequate thought to planning for large numbers of people evacuating on foot, now that there was some indication this may occur in large cities. The discussions with the practitioners also indicated they believe the usual techniques for traffic congestion management can be used. However, they assert that emergency planners need to focus much more attention during preparedness planning on evacuation scenarios that provide planning assumptions for pedestrian evacuation. The public safety practitioners emphasize that the basis of effective emergency response of any type is the development of close and continuous working relationships across agencies. The transportation practitioners add to this that the transportation agencies have traditionally responded based on decisions and directives of others. The development of intelligent transportation systems (ITS) in many cities now puts the local departments of transportation in the position of being able to make major contributions of information during disaster response as well as to provide information to the public, and especially travelers.

In conclusion, based on the information collected for this report, it seems reasonable to say that the factors associated with the emergence of a large scale pedestrian evacuation from a section of a large U.S. city are not as yet very well understood. Further focused research is needed to help

clarify the planning assumptions for managing or accommodating pedestrians in a metropolitan evacuation. Pedestrian evacuation can be seen as a phenomenon that responders should consider in order to be prepared for the potential that large numbers of people may decide to evacuate on foot, along with vehicle traffic. On the other hand, evacuation planners may want to consider under what circumstances the deliberate implementation of a pedestrian evacuation might be a preferred and feasible strategy in highly urbanized areas for most quickly getting the largest number of people out of harm's way.

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1 INTRODUCTION

1.1 Background

The hurricane seasons of the past few years produced vivid images of major highways filled to capacity with residents evacuating from coastal areas. Other less-widely publicized evacuations take place on a relatively frequent basis across the United States each year. A January 2005 study commissioned by the Nuclear Regulatory Commission cites that evacuation of 1,000 or more individuals occurs once every three weeks in this country.[1] The study, which evaluated evacuation operations over a 12-year period, indicated that most evacuations result from wildfire threats to populated areas, floods, hurricanes and tropical storms, fixed site and transportation-related industrial accidents where airborne releases of gases often dangerous to humans occur, transportation accidents, and malevolent acts. During these scenarios, emergency responder assessments of the situation may prompt the incident commanders to ask law enforcement officials, often supported by transportation agencies, to order nearby residents to leave immediately. These events typically involve the evacuation of small towns or areas around industrial complexes. Dozens to maybe a few thousand people get in the family cars and drive a few miles to a safer location, directed away from the potential hazard area by law enforcement officers and traffic barriers which also prohibit any incoming traffic.

The September 11, 2001, (or 9/11) attacks on the high-profile workplaces of the World Trade Center (WTC) in New York City and the Pentagon, just outside Washington, D.C., made real the impact of an unexpected, or "no-notice," event in a metropolitan setting. The news coverage of the events of this infamous day showed thousands of people leaving the area of the WTC on foot. The evacuation from the borough of Manhattan included not only the typical traffic congestion expected in an evacuation in the United States, but thousands of pedestrians moving along with, or among the streams of outbound and inbound vehicles. Even though numerous emergency response vehicles arrived at the WTC complex almost immediately, hundreds of others continued to converge on the immediate scene from more distant locations. When the Pentagon also was hit, national news coverage included pictures of the highways near the Pentagon filled with barely moving vehicles, much of it having originated in the District even before the Pentagon was evacuated. That morning the local and federal transportation agencies in the District were first-hand witnesses to the thousands of persons leaving government and other office buildings filling sidewalks to capacity. In places, they were spilling into the gridlocked traffic in order to make better progress or cross to take a different route.

When a large-scale, damaging event has occurred or the imminent threat of one has become known, transportation agencies working with public safety officials have traditionally had two principal objectives:

- Minimize the time it takes to get an adequate force of emergency responders to the scene where they can help victims, provide assessments, and control access.

[1] NUREG/CR-6864 v2.

- Maximize the proportion of the population moved away from the hazardous area without being subjected to other risks (e.g., traffic crashes; prolonged exposure to the danger).

Evidence that large numbers of pedestrians may be part of an evacuation raised questions within FHWA about what actions are needed to manage pedestrian traffic during metropolitan evacuations and what FHWA can contribute in this area to ensure safe and effective movement of pedestrians while minimizing their impact on vehicular movement. While the U.S. has not experienced large scale, "no-notice" urban evacuations, emergency managers responsible for urban areas understand the potential for this type of evacuation to occur following natural, industrial, or malicious emergency events. Planners continue to look to the limited U.S. experiences of evacuations in response to no-notice events in cities to uncover lessons learned, findings and best practices to use in their efforts to plan for the worst and hope for the best. These instances include the NYC and Washington, D.C., 9/11 evacuations, the Oklahoma City bombing spontaneous evacuations, the Atlanta Summer Olympics bombing, and the movement resulting from the Northeast Blackout of 2003. FHWA is trying to aid planners by studying this often-overlooked component of evacuation to aid metropolitan evacuation planners in their efforts to balance the safety and mobility needs of both vehicle and pedestrian evacuees.

1.2 Overview of the Report

The reader should consider this report a cursory view of the topic. This report addresses what is already known about managing pedestrian traffic in U.S. metropolitan evacuations. Researchers tapped a large variety of information sources for insights. Since this is a very new area of research on evacuation, little actual research on the topic exists. A more complete definition of the issues necessitates further in-depth research on temporary evacuations from large highly urbanized city centers in reaction to a sudden unanticipated event, something that has rarely occurred in the U.S.

The term "metropolitan evacuation" here refers to an emergency evacuation taken as a protective action that is implemented for a portion of a densely built-up downtown area in larger cities in the United States. The basic situation assumed for the discussion of the issues is the following:

- The triggering event will be one without notice (e.g., terrorist attack; explosion or toxic release).
- The scope of the event will be such that the emergency evacuation activity will be critical for only a portion of the metropolitan area.
- Emergency response actions will occur to mitigate the injury and damage from the destructive or threatening event even as the evacuation is taking place.
- The evacuation is expected to be temporary for those parts of the area that were not badly damaged or contaminated.

The report is organized as follows:

- Chapter 2 covers the approach for identifying literature that addresses or in some way includes the topic of pedestrian evacuation and what was discovered. The literature review was designed to touch on pedestrian behavior from a variety of disciplinary viewpoints. Newspaper accounts and findings from various types of research were examined, as well as a series of recent in-depth case reports done under the auspices of

the FHWA, to examine transportation operations during several large scale catastrophic events. In addition, some selected events were examined through publicly available "after action reports" written from the perspective of emergency response.

- Chapter 3 presents information gathered through telephone interviews with fifteen agency officials in urban areas to obtain practitioner insights. Several cities were selected based on information that the city had experienced a major emergency event or conducted robust emergency planning for downtown areas. The fifteen telephone interviews included conversations with representatives of transportation, emergency response, and emergency planning agencies in the San Francisco Bay area, New York City, Seattle, Washington, Washington, D.C., metropolitan area, and Cleveland, Ohio.

- Chapter 4 addresses examples of variables in the evacuation context and evacuation management beliefs and summarizes the discussions of the multi-disciplinary panel of eight subject matter experts that was convened to share different perspectives on the nature and management of pedestrian evacuations.

- Chapter 5 outlines conceptual approaches for achieving mobility and safety for pedestrians and minimizing interference of pedestrians and drivers with each others' mobility. Evidence of the existence of these approaches was found in evacuation implementation or planning of some cities. However, no research was found that described details or issues related to the evacuation implementation. Other approaches had not yet been implemented in an actual event involving pedestrian evacuees.

- Chapter 6 outlines research needs and provides a brief summary of different perspectives from practitioners and researchers on the topic of pedestrians in evacuations and a final conclusion about the relevance of the topic to public safety and emergency management agencies faced with the possibility of the need to handle an emergency evacuation of some portion of a highly urbanized area.

2 LITERATURE AND CASE STUDY REVIEW

2.1 Methods for Identifying Literature

The research applied several approaches to find examples of evacuations and written reports outlining evacuation characteristics in urban settings, in particular. A professional librarian conducted a conventional literature search to find written items relating to urban evacuation of pedestrians and efficient movement of emergency vehicles into a disaster area, augmenting existing resources available to the researchers. Several different computerized databases were searched to determine the state of the literature, including newspapers (Dialog and ProQuest databases), transportation journals (TRIS database), and psychological journals (PsycINFO). Researchers also sought open-source "after-action reports" from a few major incidents, drawing upon the Lessons Learned Information Sharing (LLIS) site maintained by the Department of Homeland Security (DHS) as well as other sites. In addition to these resources, the FHWA provided draft reports of several case studies of major disaster or emergency events in metropolitan areas, collected from the perspective of their effects on transportation operations. While researchers found that the search term "pedestrian evacuation" yielded mainly studies of the evacuations from buildings, planes, ships, and trains, this literature for the most part is not addressed here.

2.2 Major Findings from the Literature Review

The purpose of the literature review was to examine what is already known about pedestrian evacuation in U.S. urban areas. In short, the research found that there is little mention of pedestrians in any of the literature specifically on emergencies and disasters. It appears to be considered axiomatic that people evacuate in private cars. There is a growing literature based on research on evacuation from large buildings, but a dearth of literature that addresses what happens to building evacuees once they reach street level. This very limited record of people evacuating on foot may be either an artifact of the literature encountered or an actual characteristic of most emergency evacuations in the United States. With attention called to pedestrians in at least two recent urban emergency situations, future research is likely to examine the issue more closely.

2.3 Sources of Information on Evacuation

2.3.1 Newspaper and Internet Sources

The news article database, Dialog, covers 40 major newspapers. Starting with 1994 very few newspaper articles were found that were relevant to the primary topic of interest—major "no-notice" evacuations in urban areas. Newspaper articles on evacuation typically focused on hurricane and hazardous material evacuations, which either provided adequate warning to evacuation officials or only affected a very small, often rural, area. Several articles highlighted the need for effective evacuation planning, citing the political and logistical difficulties

experienced when creating an evacuation plan.[2] One newspaper feature article described significant crowd disasters at nightclubs, stadiums, and arenas.[3] Club and arena disasters generally occur when a large number of people rush to escape an enclosed facility and crush persons against the exit, or via crowd stampedes. The few recommendations mentioned are limited to enforcement of existing occupancy safety laws. An extensive set of brief descriptions of disastrous crowd stampedes in foreign countries was found on the website of a firm that provides consulting and facility design for events involving large numbers of participants.[4]

2.3.2 Transportation Research on Evacuation Planning

A search for relevant literature in the transportation database identified examinations of evacuation planning and of new methods for designing evacuation routes. The evacuation planning literature in this database generally was concerned with evacuation plans for a large area when either facing a foreseeable natural disaster, such as a hurricane, flood, or volcanic eruption[5], or following a destructive seismic event or hazardous materials release[6]. The majority of the articles are concerned with evacuation of a large area via passenger vehicles, so the recommendations are not directly relevant to pedestrian evacuation. However, the basic principles are similar as far as providing smooth channels for efficient egress from a disaster area. For instance, evacuation management issues related to hurricane evacuations are relevant to other large scale evacuations considered in homeland security planning.[7] First, efforts need to be made to reduce the occurrence of overreaction and panic to limit evacuation travel demand and therefore decrease the possibility of overcrowding an evacuation route. Second, transportation officials need to maintain good communication and data exchange to ensure smooth emergency management. This can include law enforcement and other emergency services, as well as access to ITS technologies and local radio stations.

Another area of literature reviewed focused on the use of emerging technologies for evacuation plan development. Technologies include geographical information systems (GIS), database management systems (DBMS), census and other descriptive population data, and dynamic route planning.[8] GIS is highlighted as the essential tool for efficient evacuation route planning, especially when linked to population and land use data. For example, spatiotemporal land usage data – information on where the population of a given area is typically located during different times of the day – can be very useful when creating dynamic evacuation routes for hazardous material releases and other localized disasters.[9] GIS has also been used to characterize the road network and identify bottlenecks and other sources of flow problems to determine optimal traffic planning during passenger vehicle-based evacuations.[10]

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[2] Dixon, 2001; Rocco, et al., 2001; Saavedra, 2001; Eisler, Bayles, & Vergano, 2001; Van Bronkhorst, 1999.
[3] Bayles & Hampton, 2003.
[4] Crowd Dynamics, Ltd.
[5] Pal, Graettinger, & Triche, 2003.
[6] Petrucelli, 2003.
[7] Wolshon, 2004.
[8] Campos, da Silva, & Netto, 2000; Li & Wang, 2004; Pal, Graettinger, & Triche, 2003; Alam, & Goulias, 1999; Abkowitz, & Meyer, 1996.
[9] Alam & Goulias, 1999.
[10] Abkowitz, & Meyer, 1996.

2.3.3 Psychological Research

Physics models have been used by psychologists to characterize pedestrian flow of sets of individuals exiting a room, moving through corridors, and moving around obstructions in both normal and panic situations.[11] Such modeling is used to characterize mass behavior of pedestrians, including reduced attention, ignoring side exits, and "herding." This modeling indicates that in constricted areas "faster is slower" – that is, as desired velocity increases, actual flow velocity typically decreases due to increased forces as pedestrians push toward an exit. Crushing fatalities occur during room egress due to increased forces as the crowd pushes toward the exit. The model shows that placing a barrier close to the exit can distribute the equilibria of these forces and serve to increase exit efficiency. Similarly, placing columns along a walkway can effectively segregate flow into "lanes." Finally, the model illustrates that a temporary widening in a narrow corridor can actually reduce flow velocity with high pedestrian density due to bottlenecking where the corridor returns to it normal width. The observations from these studies have relevance for the design of pedestrian facilities in cities that could contribute to safer pedestrian evacuation.

Several articles examined human behavior under the stress of emergencies.[12] These suggest four cognitive stages that people experience when responding to a stressful emergency event: 1) defining the situation; 2) devising a plan; 3) carrying out the plan; and, 4) looking back to assess whether the action solved the problem. People first attempt to gather available information about the situation to help them decide what action to take. This information includes both the present environmental status as well as referring to their past experiences in dealing with emergencies. Environmental information ambiguity is common in emergency situations. Typical reactions of people when information is ambiguous include: ignoring the situation; looking for information by asking questions; or moving toward the danger area to investigate. These reactions consume precious time and can greatly affect the outcome of the evacuation.

Social scientists who study disaster behavior hold that it is a very common misperception that people confronted with a threatening situation will engage in irrational and non-functional behavior often referred to as "panic flight." Much of what might appear as random and non-functional behavior to an outside observer of a group of people when they become alert to a danger is actually highly rational because it is related to first ascertaining the status of other family members or friends before engaging in appropriate evacuation behavior. Numerous researchers and reviewers of research conclude that irrational panic behavior on the part of the public when warned of an imminent danger is not something emergency managers will need to contend with.[13] Nonetheless, the specter of panic makes for dramatic movies and high newspaper readership, so it continues to be perpetuated by the media.[14] Research findings do contain evidence that when community officials and emergency managers believe people will flee in panic and be hurt if alerted to a serious danger, they may withhold critical information

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[11] Helbing, et al., 2002.
[12] Lang & Lang, 1961; Drabek, 1969; Sugiman & Misumi, 1988; Sorensen, 1991; Proulx, 1993; Riad, Norris, & Ruback, 1999; Pacheco-Costello, Maguire, & Chang, 2002; Saloma, et al., 2003.
[13] Quarantelli, 1981; Keating, 1982; Drabek, 1986; Zelinsky and Kosinski, 1991; Tierney, et al., 2001; Feinberg and Johnson, 2001; Fischer, 1998.
[14] Mitchell, et al., 2000; Fischer, 1998; Walters, 1988.

that could help people avoid injury or death by enabling them to act more quickly to take appropriate protective actions.[15]

2.3.4 Evacuation as Policy

During the early 1980's the newly created Federal Emergency Management Agency was mandated to carry out a civil defense policy of crisis relocation for population protection in the event of a nuclear attack.[16] Issues related to relocating the population of communities thought to be potential targets were examined. One study examined more than twenty case studies of city evacuations in different countries and for various reasons, in order to address the efficacy of long-term evacuation of cities as a civil defense strategy. Crisis relocation planning was viewed negatively by many communities, which objecting to the possibility of being designated as host communities. The policy was never fully implemented.[17] However, FEMA fostered "all hazard" planning and temporary evacuation for population protection from natural hazards became more common. As pre-event evacuations became more common in the face of impending natural disasters, research was focused on evacuation warning response.

2.3.5 Evacuation Decision Making

Research on decision-making suggests that people may only consider a few options, rather than considering all available information. Under time pressure, people tend to give priority to familiar options and disregard unfamiliar options that are perceived as more likely to increase danger. For example, emergency exits are often disregarded because building users have no experience in using them and therefore are unsure about where they lead. This theory explains why people evacuating from buildings tend to use the main entrance as an exit rather than emergency exits.

The goal during evacuation is to keep stress low to enhance people's performance in coping with the situation. Excessive stress reduces decision-making abilities and creates increased opportunity for irrational (panic) behavior. Information reduces both confusion and time spent denying the situation. Three information characteristics have an impact on interpretation of a situation: quality, quantity, and relevance. People need to know specific information regarding the situation as well as the correct course of action. Information should be provided as early as possible to get people moving toward safety. Delays in warning may lead to situations that negate the ability for people to make good decisions and thus fatalities occur.

An analysis of the 1987 King's Cross Underground (London subway) station evacuation tragedy provided several important observations about how to improve evacuation success including the effectiveness of different types of emergency evacuation instructions.[18] For example, with respect to type of information provided to evacuees from the subway station the research indicated that announcements with specific information and instructions were more effective than announcements consisting of instructions or personnel simply directing evacuees toward

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[15] Fischer, 1998; Scanlon, 1991.
[16] Perry, 1982.
[17] May and Williams, 1986, Chap. 8.
[18] Proulx & Sime, 1991; Proulx, 1991; Proulx, 1993.

exits. The study also found that evacuees are more likely to follow the instructions of uniformed officials (e.g., police and firemen) than subway workers, due to their perceptions of the authority and confidence of the policemen. In a similar study, researchers found that evacuations were faster and more effective when evacuation officials led one or two evacuees from the situation than if they simply shouted instructions and used gestures toward the exits.[19] Thus, it is critical that officials assisting evacuees have good information about the situation and safe evacuation routes, in order to provide appropriate instructions.

Several reviews of the large body of social science research on disasters include the findings on warning compliance and decision making of individuals in disaster evacuation. Important factors in an effective evacuation process include specific information about the source of the danger and urgency of evacuation, specific instructions regarding what to do, and the use of uniformed and authoritative personnel to give instructions. [20] Non-residents (e.g., tourists and business travelers) who find themselves faced with emergency evacuation will be unfamiliar with place names, routes, distances, and facilities, making them particularly dependent on hotels and public safety authorities for assistance.[21]

Timely public evacuation is related to individuals defining themselves as being in danger and believing that leaving the area is appropriate.[22] An examination of the factors related to how quickly people begin to evacuate, found that the steepness of the mobilization curve (i.e., what proportion leave within how many minutes) is related to the perceived severity and timing of the impending threat.[23] This suggests that, for events that have occurred with no warning, the perceived severity of the threat may determine how many people are evacuating simultaneously.

Researchers, especially those who have studied public response to warning and evacuations instructions, acknowledge that there is not as yet direct evidence as to what might be the public response in the United States in the face of an incident created through the malicious use of an agent in the category of weapons of mass destruction (WMD). Two examples were found of scholars who have made extrapolations from what is known about the behavior of the public in past disasters to what might reasonably be expected in the event of a terrorist incident involving some chemical, biological, or radiological weapon. Both are optimistic that what is currently known about the reactions of the public and the need for interagency coordination for complex responses during disasters are good predictors of behavior in the face of not-yet-experienced disaster agents.[24] They add the caveat that aggressive public education to create public familiarity with new hazards and appropriate responses is necessary.

2.3.6 Sheltering-in-Place

In situations of inadequate time for a very large population to clear an area in the face of, for example, an airborne release of a dangerous substance, “sheltering-in-place” can be employed as

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[19] Sugiman & Misumi, 1988.
[20] Drabek, 1986; Lindell & Perry, 1991; Lindell & Perry; 1992; Tierney, Lindell & Perry, 2001.
[21] Drabek, 1995; 1996; 2000.
[22] Fitzpatrick & Mileti, 1991.
[23] Sorensen, 1991.
[24] Fischer, 1998; Perry & Lindell, 2003.

a protective action. This action should only be used if adequate protection is possible. However, having people sheltering in place, that is, staying where they are once the period of danger is in effect, reduces the numbers of persons who become part of an evacuation stream or who have to be provided public transportation. Even though some surveys have found fairly large proportions of people saying they would be willing to shelter in place, or reporting that they will shelter in place "the next time" to avoid the traffic congestion and hassle of evacuation, there is little research to indicate what proportion actually will shelter rather than leave.[25] This means that the proportion of the population at risk that will stay or go cannot be easily predicted. Activities related to managing evacuation need to be maintained, even if the protective action of sheltering-in-place is recommended or ordered.

2.3.7 Modeling Pedestrian Crowd Behavior

Pedestrian behavior has been the subject of empirical studies since the 1960s. The major goal of most of these studies was to provide information to develop design guidelines for pedestrian facilities (such as sidewalks) and to aid in the design and construction of facilities that are safe, efficient, and pleasant to use. These studies have used manual logging of observations, video cameras, time lapse photography, and ultraviolet/infrared sensors to study the way pedestrians normally behave.[26] Other studies have focused on the evacuation of buildings and other structures (e.g., ships). The proceedings from the first International Conference on Pedestrian and Evacuation Dynamics, held in 2001,[27] and subsequent conferences in 2003 and 2005 include presentations from across several disciplines, including architecture, civil, naval and fire safety engineering, physics, computer science, and mathematics. None of the presentations address issues of crowd dynamics that occur when people evacuating a large building become part of the sidewalk and roadway traffic congestion

Crowd modeling and crowd management technology are used increasingly by consultants to address practical issues regarding pedestrian planning and design in terms of both crowd safety and emergency evacuation. Specific pedestrian flow models have been developed to simulate the flow of large groups of pedestrians, often those associated with large-scale evacuations from large buildings/offices/sports stadiums, or conveyances like airplanes and ships or evacuation strategies for multi-building sites.[28] Highly sophisticated modeling approaches such as these may be appropriate for planning for evacuation in areas with very high pedestrian densities likely to be created as workers evacuate from large office buildings.

2.4 Case Studies of Transportation Operations in No-Notice Events

The perspective of the transportation agencies is represented in the series of case study reports sponsored by the DOT/FHWA, Office of Operations, titled *The Effects of Catastrophic Events on Transportation System Management and Operations.* The draft case studies were focused on the types and timelines of transportation disruptions that occurred in conjunction with several

[25] Lindell and Perry,1992:242-244.
[26] Willis, et al., 2002; Helbing, et al., 2002. Helbing, et al., (2002) cites 153 references to American and European pedestrian and evacuation studies.
[27] Schreckenberg & Sharma, 2002.
[28] E.g., Crowd Dynamics Limited.

catastrophic events and how they were resolved. The two studies in New York City contain some observations of the phenomenon of large numbers of people leaving the city on foot in each of the events. This was treated more as one of the disruptions to transportation than as a focus for analysis. The overall set of case studies, many still in draft when reviewed for this study, includes the following:

- New York City, terrorist attack, September 11, 2001;
- The Pentagon and the National Capitol Region, terrorist attack, Sept. 11, 2001;
- Baltimore, Maryland, rail tunnel fire, July 18, 2001;
- Northridge, California, earthquake, January 17, 1994;
- Great Lakes Region, Northeast Blackout, August, 2003;
- New York City, Northeast Blackout, August, 2003.

Revised versions of the reports on the Northeast Blackout, one for the Great Lakes Region and one for New York City, have since been released, as well as a companion report titled *Comparative Analysis* which considers all six cases.[29]

The most information on pedestrian behavior was found in the reports describing the two major incidents in New York City—the 9/11/2001 attack on the World Trade Center and the Northeast Blackout in 2003. These reports described instances of pedestrian evacuees encroaching on roadways or presenting a potential problem for emergency response vehicles. Transportation authorities were concerned about large numbers of pedestrians as well as vehicles using the same bridges, because the authorities did not consider this situation safe for pedestrians and also felt that the heavy congestion associated with both cars and pedestrians on these bridges might hinder the progress of emergency responders trying to get into the city over the bridges. Recommendations included approaches to keep pedestrians and vehicles separated. The two major approaches described are to: assign certain roads and tunnels or bridges to only vehicles and others to pedestrians; and, assemble the pedestrians in a staging area near a traffic choke-point, where they can be put on buses to be taken across a bridge or through a tunnel as part of the vehicle traffic.

There were major situational differences between the 2001 attack on the World Trade Center and the regional blackout in New York City two years later. In the 2001 event, the main impact scene was a fixed location; the people streamed out of the affected office buildings during approximately two hours and went off in all directions. For the most part, private vehicles were not available to evacuees from around the World Trade Center complex. Thousands of people left Lower Manhattan on foot. A large proportion of them were occupants of office buildings, so it is assumed their preferred destination was their home. Many apparently walked several miles to reach their residences or other preferred destinations. For others, their evacuation was carried out in part by walking and in part by taking various forms of transportation. For example, many evacuees walked south to the ferry terminal to catch a ferry or other boat to cross the river, or walked north to an operating subway station or to staging areas for bus transportation that were eventually established.

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[29] These reports are available on the FHWA's web site for Emergency Transportation Operations (ETO). < http://www.ops.fhwa.dot.gov/opssecurity/case_studies/index.htm > .

The other event where thousands of people left the city on foot was associated with a large scale power outage that affected all or part of several northeastern states. When power went out in New York City, it became difficult for most people to continue working. Tens of thousands of workers left their office buildings all across the city in a relatively short time. Since the cause of the situation was known and not viewed as life threatening, the major impetus for the surge of traffic and pedestrians away from the business areas was more akin to a homeward commute when the workday is over than an urgent need to leave a hazardous area. A high percentage of the office building occupants probably had taken mass transit to work, but the total loss of power meant neither the subways nor commuter trains were operating. The alternatives were to walk, find a bus, or catch a ferry. The vehicle traffic was gridlocked for several hours because traffic signals were not operating and public safety officials were engaged in such activities as rescuing people from stalled elevators rather than directing traffic. The studies of both events made the same recommendations: plan for ways to keep pedestrians separate from cars at the major chokepoints (e.g., bridges), and establish and publicize transportation hubs where pedestrians can assemble in order to catch public transportation out of the city.

When the two New York City case studies are compared to the others, three observations stand out as related to situations associated with pedestrians as part of the evacuation mix.

- During evacuations, the emergence of large streams of people evacuating on foot may be most likely to occur in areas with high population densities where residents/workers rely heavily on mass transit, especially if some major portion of the mass transit system is disrupted at the same time.

- Pedestrian evacuees and those in private vehicles will converge at those places where natural (e.g., river) and artificial (e.g., tunnels, bridges) barriers create "chokepoints" that limit egress route options. Mobility of both pedestrians and motorists is reduced, and safety problems are created when pedestrians walk in the same lanes being used by cars. Traffic managers can predict where this will occur. The city's evacuation plan can include solutions for minimizing this occurrence, such as staging bus transportation at these points for moving the pedestrians through these areas.

- Only the two New York City case studies included a description of pedestrians as part of the transportation challenges created by the event. Both reports concluded that in instances involving large masses of pedestrian evacuees, pedestrian safety can be enhanced by designating separate routes for pedestrians and vehicles. This can include the designation of specific streets, as well as bridges or tunnels where possible, for either pedestrians or vehicles. This calls for pre-planning about traffic control, transit options, and instructions to the public to achieve this separation as quickly as possible.

2.5 Emergency Response After-Action Reports

Several emergency response after-action reports were located for events that involved some type of evacuation. Best practice in emergency response calls for reports to be prepared following any exercise or response event, in order to identify where improvements in the response actions can be made. When information is handled as "lessons learned" and not for assigning blame and punishing mistakes, after-action reports can provide details about and insights into problems

associated with an event, how the response was managed, and how adaptations were made or could have been made to the basic plan. However, after action reports typically do not find wide distribution because of concerns that the information will be misused.

After-action reports most typically are prepared by the emergency responders and focus mainly on activities at the scene of the impact, including fire fighting, search and rescue, medical care and access control. These emergency response reports contain very little about what the non-responders were doing, with the exception of those who are badly injured and are thus an object of a first response function. Transportation operations and evacuation modes outside the "hot zone" of the response activities are seldom addressed in these reports. Nonetheless, some ideas about what people did once they exited a building or area, for example, can be pieced together from the details about response.

After action reports from several major emergencies perpetrated by terrorist actions and with no warning were reviewed. These are: a vehicle bomb detonation in the basement under the World Trade Center Tower 1 and the Vista Hotel in New York City in 1993; the vehicle bomb explosion in front of the Oklahoma City federal building in 1995; the Sarin gas releases in the Tokyo subway in 1995, and the deliberate crash of an airplane into the Pentagon on September 11, 2001. A report prepared by city agencies on the blackout response in New York City in 2003 also was reviewed. These reports provide insights into what it was like at the scene and to some extent, the actions of people evacuating from the impacted area.

A search on the internet identified several accounts, mainly newspaper articles, about the bomb at the Olympic Games site in Atlanta and the recent Madrid, Spain, train bombing. However, the articles focused on likely perpetrators and the number of injured. No information was provided on whether or how the survivors left the area. The literature review had been prepared before the suicide bombs in the London Subway or the levee breaches around New Orleans during Hurricane Katrina in 2005.

2.5.1 New York City World Trade Center Bombing, 1993

This set of articles[30] was prepared mainly by fire service people who had carried out different functions under the incident command, and was originally published in a fire service journal. The evacuation of the Vista Hotel and Towers 1 and 2 at the World Trade Center (WTC) involved an estimated 50,000 people (about 25,000 from each of the two towers), as well as several hundred from the 850-room hotel. At that time, it was characterized as the "largest building evacuation in history."

The evacuation is described as a self-evacuation, because the tower occupants began to evacuate without being told, apparently as a reaction to the uncertainty created by the information about an explosion in the basement. A few started, and more and more joined in. Early in the course of the response, the fire department's assessment of the situation determined that such a building evacuation was unnecessary. However, the responders did not think the evacuation could be stopped without confusing and frightening people. The fire department concentrated initially on

[30] United States Fire Administration. (n.d.)

getting the fire out in the garage, in order to limit the spread of the smoke through the buildings. Fire personnel who went up in the towers found people needing assistance and medical care, including women in labor. Several hundred people were trapped in the various elevators. According to the report, it was eleven hours before everyone was out of the towers. In contrast, the Vista Hotel management had ordered guests to evacuate immediately and then checked each floor to ensure it was clear. The 800-room hotel evacuation took about 10 minutes, aided by the fact the hotel was at its lowest occupancy period for the day.

The report indicates that many people who came down out of the hotel and towers stayed in the lower levels once they got there, relieved to be down and safe and not wanting to go any further. Officials had determined the danger was over and it was bitter cold outside. It is likely that many of the hotel guests were unfamiliar with the area and transportation options. The presence of emergency response vehicles around the area of the explosion probably prohibited taxis from coming very close to the hotel and towers.

Some EMS teams performed triage in the large areas of the lobby and mezzanine even though the air was still smoky. They prepared the injured for transport as rapidly as they could. Others worked with the injured up in the towers. The EMS teams tagged injured victims for transport to area hospitals by police car, school bus, or mutual aid ambulance. The ambulances of the NYC EMS teams generally remained parked at the scene while the EMS squads worked inside with patients. Hospital records indicated that just over 400 people had gone to hospitals for care, although not necessarily immediately upon leaving the scene. Many of them had made their way home, the adrenalin had worn off, and then they had gone to the hospital because they started to feel bad. The hospital closest to the scene received about 200 self-referrals into the hospital over the first 12 hours. No information in any of the reports indicated how many came on foot.

The WTC complex has about 16 exits, so people were able to leave the area and disperse in several different directions. Many people left their offices without their coats so were inappropriately dressed to spend an extended time outside the building in the freezing weather. Hundreds gathered in a large food court area across the street. The EMS teams conducted quick assessments at several exits and set up to provide treatment in the food court location. According to one report, there were six fatalities and 1,042 injuries associated with the bombing and evacuation. No information is given on the actions of the thousands of evacuees who did not stay at the scene. No mention is made of the status of the subway service.

The bombing and response activities were generally limited to a small area of the city immediately around the WTC. An indication of the limited scope of the event compared to the overall metropolitan context is the fact that the EMS received about 3,000 other calls for service across the city that same day, unrelated to the WTC bombing scene.

These observations come from the perspective of the emergency responders so they don't extend to what was happening beyond the event scene. The observations indicate that large numbers of people stayed in the vicinity at least for a time but don't say anything about the impact on city traffic of the probably tens of thousands of others who left the area. Notable observations for consideration in urban evacuation planning are the following:

- The evacuation of the WTC towers was initiated by the building occupants themselves, without specific guidance from authorities. It took almost all day to clear the two buildings. This suggests that the number of people exiting onto the streets at the same time was minimized. Since that time, building managers and businesses have begun to place more emphasis on the design of procedures for quickly evacuating high rise buildings. This will result in very large numbers of people emerging from a large office building at the same time. Some types of events may result in several large office buildings being evacuated at the same time. Authorities need to have plans for how to provide information to these masses of people that will result in their moving quickly away from the vicinity and the hazards created by the event.

- Injured but ambulatory evacuees are likely to leave the area without receiving a medical assessment or treatment. They may go directly to a hospital to receive care, or present themselves at a hospital many hours later when they begin to experience symptoms of the injury or exposure. This suggests that authorities need to consider the implications of these two behaviors when planning how to support an emergency evacuation. For example, the route to the nearest hospitals may be within the zone that authorities want to clear which results in these injured persons being directed to move in a different direction. Also, if people are going to walk long distances even though injured or contaminated, for example, authorities need to consider deploying some of the medical resources to points along the routes designated for pedestrians.

- In large, highly urbanized places, a major emergency event and its impact are likely to affect a relatively small portion of the overall area and its activities. The unaffected areas of the city provide safe places where the authorities can stage transportation and other services for pedestrian evacuees.

2.5.2 Oklahoma City Murrah Federal Building Bombing, 1995

This after action report[31] is related to the emergency response, and provides details on what happened to the building occupants specifically. The noise and smoke from the explosion triggered the self-dispatch of several fire units to the scene within minutes. Other responders were officially sent to the scene after about ten minutes, as the magnitude of the event became evident. In addition to the quick arrival of eleven fire units, there was also an immediate convergence onto the scene of workers from other downtown buildings who tried to help with the search and rescue activities.

The Murrah Building had about 650 occupants at the time of the blast. A major portion of the structure was destroyed and more than 100 occupants perished. The blast also caused damage to other buildings nearby, and injuries to people from flying glass from blown out windows and other debris. The report mentions only the building occupants leaving the scene who were injured; no mention is made of the non-injured and whether they were able to use their vehicles to leave the area. Mention is made of the transit system being brought into the response effort in order to evacuate the residents of a nearby apartment building, and efforts to maintain service

[31] City of Oklahoma, 1996.

along regular routes near the scene as well as deliver supplies and take exhausted responders back to their stations to rest. Evacuation of buildings in the downtown area that were not directly affected by the blast was at the discretion of the management; no mention is made of how many evacuees might have been involved.

Eleven fire units arrived at the scene within minutes, followed by another ten units in about ten minutes. The fire units followed established procedure in taking different routes to the scene, and took up positions around the building. The report does not indicate whether any of the fire units encountered traffic congestion. Many units reported coming across "walking-wounded" as they approached the area, and stopped to see if assistance was needed before proceeding to the scene. Since a hospital is located only six blocks from the scene, it is likely that these injured pedestrian evacuees were headed to it for treatment.

Emergency medical services (EMS) units also came upon the injured pedestrians. Some units set up triage sites well away from the Murrah building, somewhat distant from those with the worst injuries. Many injured stopped for treatment at the triage sites and were transported to various hospitals. About 200 injured persons were treated and transported to hospitals under the direction of EMS during the first day. Final reports put the number of injured treated at hospitals at about 425, and those treated by private physicians at around 200. Thus, many sought treatment at a hospital, sometimes several hours after the explosion.

Initial actions by law enforcement included establishment of a traffic perimeter to deflect non-emergency vehicle traffic away from the response scene. The highway patrol diverted traffic from certain exits of the Interstate, which most likely was still crowded with morning commuter traffic. No mention is made in the report of traffic congestion beyond the response perimeter or of large numbers of non-injured pedestrian evacuees. A mention is made of how well the incident command managed to keep the street area right around the scene from becoming congested, giving the responders room to work. This was attributed to the fact that many of those in the incident command had attended a course at the Emergency Management Institute (EMI) run by FEMA, and had received instruction about the need to control congestion at the immediate scene. The report also notes the large number of fire and EMS units that arrived to offer mutual aid, although not requested, and the difficulty the incident commander had keeping track of all of them.

The evacuation challenges of this event contrast sharply with those of the evacuation of the WTC towers and adjoining hotel in New York City noted earlier. The number of building occupants evacuating from the area was probably less than a thousand. A high proportion of the survivors were injured by the bomb blast, suffering from lacerations and glass shards in their eyes. The weather was pleasant. Mass transit was not likely the dominant mode of transportation for the building occupants. No information is provided on the availability of personal vehicles for use in the evacuation. However, it is known that many of the less severely injured left the scene on foot, but were picked up and transported under EMS direction to hospitals for further medical care.

Two notable observations from this report are the following:

- People in impact zone don't necessarily leave. Rather than evacuating, some civilians may immediately converge on the event scene to assist with rescue. In this instance the

impact phase was over. In an instance where contamination or exposure to a continuing release represent a hazard to civilians, they need to be instructed to leave the immediate area.

- Emergency responders and vehicles will continue to converge on the scene, even though they have not been requested. They may not be aware of local plans for designation of routes for emergency vehicles. This can represent a hazard to the pedestrian evacuees if they are spreading into the street as they move away.

2.5.3 Tokyo Subway Sarin Gas Attack, 1995

The Sarin gas attack was planned to exploit the confined nature of a crowded subway system. Thus, the transportation system itself was an element of the attack. The author of the report[32] examined the response to the attack and identified several organizational characteristics of the emergency response system as causes of inappropriate actions that were taken initially, and discusses what has been done to improve emergency response procedures for the transit system.

The attack provided one of the first opportunities for emergency responders to work in an environment in which a weapon of mass destruction (WMD), in this case a nerve gas, had been released. In the worst case, the nerve gas release could have resulted in many more casualties and the complete closure of a subway system that carries millions of passengers every day. Since the nerve gas was released at multiple locations throughout the subway system, a need for emergency response arose quickly at or near the release locations as people became sick. The potential first responders, the transit workers on the subway, viewed the receptacles and leaking gas as just another mess to be cleaned up. The subway trains continued to run, and people continued to board the train at each station even though something was apparently wrong when a few people were noticed staggering out of the subway train at various stations and making their way with obvious difficulty to the street level. More than an hour had passed before the calls about sick people from fifteen or more subway stations were recognized as related and as cause for emergency response. When the emergency responders arrived at the various subway stations, they rushed down to see what was going on. They did not understand what was happening, and they had neither the training nor the equipment necessary to deal with an agent like Sarin gas.

The report suggests that large numbers of subway riders left the train and went up to the street level following the gas release. The sick staggered about or lay in the street, where other passengers and by-standers tried to help, and eventually medical care and transportation was provided for several hundreds of victims. The authorities probably knew within two hours that the agent was Sarin, but withheld the information from the public. Later that same day the subway system was restored to full operations. People who had witnessed the scene at a subway station were confused and frightened, and thousands sought medical care throughout the next few days. The report did not indicate that there was any evacuation with the exception of people leaving the trains for the street.

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[32] Pangi, R. 2002.

One observation from this report relevant to pedestrian evacuation is the following:

- The malicious event was designed to occur in several places within a very short time frame. In situations like this in an urban area, streams of pedestrian evacuees may be forming in several locations at once. This presents a complex challenge for directing and accommodating pedestrian evacuees in order to provide safe routes and minimize the impact on the vehicular evacuation traffic.

2.5.4 Pentagon Attack, September 11, 2001

This lengthy after-action report[33] provides more than two hundred recommendations for ways to improve emergency response to catastrophic events in Arlington County. However, it is like the other reports in that it contains sparse details on the process of evacuation of the building occupants. The Pentagon complex covers 29 acres and employs a workforce of about 23,000. The complex includes an underground station of the Washington Metro system.

Almost immediately after the plane struck the west side of the Pentagon, the Defense Protective Services for the Pentagon called for a full evacuation and assisted people to exit out the north side of the building. The evacuation of the building was accomplished in about an hour. About 20,000 people left the scene within the first 90 minutes or so after impact. The report notes that the parking lots emptied of cars as the evacuated employees who had driven to work left the area.. A few hundred people stayed to assist with the rescue and treatment of other employees. Casualties included 139 killed by the impact and about 100 injured who were treated and transferred to hospitals. Within two hours EMS activities could be re-directed to other areas.

A contributing factor to the extraordinary traffic congestion reported in and around the county was the release of government employees from work as information became available about the attack on the World Trade Center in New York. The plane had not yet hit the Pentagon when a portion of the evacuees from the District started their evacuation toward Arlington County. By the time the Pentagon was hit, all roads, bridges, and highways in the area were well over capacity. For people evacuating the Pentagon in private cars, the only option was to join the crawling traffic. Had the attack on the Pentagon occurred at the same time as that in New York, the transportation and traffic managers undoubtedly would have made different decisions for the evacuation. For example, they might have directed the traffic leaving the District away from the routes most needed for emergency responders to get to the Pentagon and evacuated employees to leave in their cars. Or they might have simply closed the highway closest to the Pentagon. As it was, the unanticipated surge of drivers leaving the District in reaction to the news about the WTC attack initially took any route they chose. This eliminated options for selecting some routes for specific uses related to the situation at the Pentagon.

The report does not mention pedestrians specifically as part of the congestion. Some members of the response organizations were delayed two or three hours by the traffic as they attempted to report to the response scene. However, dozens of mutual aid units were able to reach the impact site at the Pentagon as the employees from the Pentagon were evacuating from that direction.

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[33] Titan Systems Corporation (n.d.)

Aid units encountered pedestrians in the Pentagon parking lot where they provided medical care to employees who hailed them. By 1:00 p.m., there were an estimated 3,000 persons at the scene, acting in response roles.

A characteristic of this event was the merging of two evacuation streams: one composed of government employees who were leaving work at their own discretion and the other composed of Pentagon employees leaving a facility that had sustained an attack. The subway could not be used in the evacuation because service at the Pentagon Station was cut off temporarily, for security reasons. The bus transfer point normally serving the Pentagon could not be used once the highway exits serving that area were temporarily closed, also for security reasons. Thus, anyone who had used mass transit to get to work had to find some other mode for the evacuation. Law enforcement personnel directing traffic for routing the Pentagon evacuees away from and emergency workers toward the scene had fewer options because of the surge of traffic already evacuating from the District.

2.5.5 Northeast Blackout, New York City, August 2003

This report[34] was prepared at the request of the Mayor of New York City and addresses ways the city could be better prepared for an emergency like the widespread, long blackout that occurred in August 2003. The New York City Emergency Response Task Force members included representatives from the private and non-public sectors and City officials. The Task Force gathered information to determine how six broad areas of city operations, one of which was Transportation, were affected by the blackout. The power outage shut down subway and commuter rail service completely. As a result, the rest of the transportation system was overtaxed. Surface traffic congestion included vehicles in gridlocked intersections and pedestrians streaming onto bridges. The traffic on Manhattan Island, where about 2 million people may be found on any week day in the business district at the southern end, came to a complete stop. An important factor in the evacuation was the interest on the part of the businesses owners and workers in the city to reach a safe place before nightfall.

Since the blackout occurred in the early afternoon, the evacuation resulted in a major increase in traffic congestion earlier than a normal rush hour, but one that lasted three to four hours. The demand on the ferry system for transportation out of the city was about 140,000 more passengers than usual. There were long wait times and a lack of crowd control. On the roadways, the traffic congestion caused by drivers leaving the business districts created difficulties for essential employees coming in to deal with emergency problems. Dissemination of traffic information through the broadcast media, normally provided by two major, independent traffic monitoring centers, was severely hampered by the power outage. There was no central source for reporting and disseminating all transportation information during this large-scale out-flow of traffic across jurisdictional boundaries.

The Task Force made thirty-five recommendations for improving the city's ability to respond during an emergency, with five recommendations related specifically to transportation. One recommendation was to link the Metropolitan Transportation Authority and the Port Authority of

[34] New York City Emergency Response Task Force. 2003.

New Jersey to the City's Joint Traffic Operation Center, to make all transportation information available in one command center. This integration would support a more regional approach and facilitate coordination during large-scale evacuations. Another recommendation was to conduct transportation planning to maximize the use of all available transportation, including school buses, ferries, private buses, taxis, liveries and commuter vans, in conjunction with designated transportation hubs for moving people out of the city or back to the city to report for work. The Task Force recommended that an inventory and assessment be made of all available waterborne resources, both public and private, that could be called upon to meet short term surges in demand for pedestrian transportation across the rivers.

The Task Force also recommended that the city develop an emergency transportation plan that would optimize the use of facilities and expedite high-priority trips. Such a plan would consider implementation of emergency roadway restrictions to facilitate emergency vehicle access inbound to Manhattan, lane reversals to facilitate evacuation, and dedication of certain facilities to pedestrians, mass transit vehicles, essential personnel, and critical deliveries.

This evacuation event is notable for its scope. The base population contributing to the number of evacuees was at least 2 million, a substantial proportion of whom worked in the city, but lived elsewhere. The circumstance triggering the evacuation was not in one or two fixed locations, but everywhere; it had a sudden onset and an uncertain end point. Many people who wanted to be somewhere else by nightfall began to evacuate shortly after the power went off. A substantial amount of capacity of the heavily used mass transit system was incapacitated, stranding an unusually large number of people without transportation. Even though the borough of Manhattan is relatively small in area, evacuation was hampered by the presence of physical barriers (water, bridges, tunnels) in all directions which created choke points for the evacuation traffic.

For most New Yorkers, who are familiar with the circumstances of traffic congestion and limited routes, this was more along the lines of a particularly difficult commute than an evacuation. There was no need for first responders who would treat people suffering from injury or shock, as there had been with the attack on the World Trade Centers two years previously. Still, the emergency response demonstrated the need for better transportation planning to facilitate future emergency evacuations, especially under such adverse conditions as the loss of appreciable capacity of the mass transit system.

3 INTERVIEWS WITH PRACTITIONERS

Interviews were conducted by telephone with practitioners to obtain information from the perspective of representatives of transportation, emergency response, and emergency planning agencies. Contacts included agency officials who had operational experience with an emergency evacuation in an urban area or had engaged in planning for urban evacuation where pedestrians were considered.

3.1 Selection of Evacuation Events

The most relevant information on pedestrian evacuation identified in the literature review came from the transportation case studies (see Section 2.4). From these studies, it is reasonable to expect that emergency evacuations involving large numbers of people on foot might be necessary in urban areas with a relatively high use of mass transit for commuting to work. The extensive blackout of the Northeast in 2003 and the terrorist events of September 11, 2001 stand out as notable events where appreciable numbers of people evacuated part of a large city without using a private vehicle.

Very little information was found using key word searches and online data bases for reports on evacuations. The searches covered newspaper articles, the National Transportation Safety Board accident investigations, and federal disaster declarations. The results were mainly examples of evacuations associated with transport-related hazardous material spills and toxic releases in rural or small community and industrial settings, and evacuations prompted by hurricane warnings and flooding disasters.

The search for practitioner thinking on pedestrian evacuation was broadened to include evacuation planning. In recent years, the emergency preparedness community has moved away from plans for specific events, to an “all-hazards” philosophy. This approach is grounded in the observation that a basic concept of operations serves to guide response to terrorism attacks as well as emergencies related to natural events and technological breakdowns, with a few adaptations made depending on the nature of the event. The 9/11 attacks provided many important lessons to transportation officials and emergency planners because of the self-evacuations that occurred. Images in the media showing outbound pedestrians crowding the bridges in New York City may have prompted emergency planners in other cities to consider pedestrians as part of the evacuation mix. This expanded search yielded a few examples of emergency evacuation planning.

Fifteen representatives of transportation, emergency response, and emergency planning agencies agreed to participate in an interview about a relevant emergency event or planning activity. These interviews were conducted over the phone by the principal investigator. The notes from the telephone interviews were reviewed by the respondents and corrected as necessary. The urban area and the related emergency or planning activities are listed below.

Table 1. Evacuation Situations Selected for Interviews with Practitioners

Location	Characteristic of Emergency Evacuation
Washington, D.C., metropolitan area Example of: Sept. 11, 2001, attacks on the World Trade Center in New York City and the Pentagon outside of Washington, D.C.	On the morning of 9/11, 2001, a large number of people spontaneously left their downtown Washington, D.C., offices or reversed their morning commute upon news of the attacks in New York City and then at the Pentagon. Unanticipated by authorities, this voluntary evacuation was characterized by initial gridlocked traffic and large surges of pedestrians on sidewalks and at mass transit stations for outbound routes. With no direct impact in the District, there was no surge of inbound emergency vehicles. Accounts indicate that many people walked relatively long distances, most assumed to be headed for their residences in the suburbs.
Cleveland, Ohio Example of: Sept. 11, 2001 evacuation of tall buildings which led to large scale evacuation from the downtown area.	On the morning of 9/11, 2001, city officials requested evacuation of the taller buildings in downtown Cleveland, based on information about the projected flight path of one of the hijacked airliners. This evacuation activity along with the news of the attack on the World Trade Center resulted in a spontaneous evacuation by large numbers of others in the downtown. Most people retrieved their cars and drove out of the downtown area, in a slow but orderly traffic flow facilitated by law enforcement, with transit riders waiting for buses and trains. With no actual impact, there was no surge of inbound emergency vehicles. Following 9/11, a downtown evacuation plan, assuming both vehicle and pedestrian emergency evacuation was developed and publicized.
San Francisco Bay Area Example of: Transportation system disruptions from the 1989 earthquake in the Bay Area. A large and unpredictable fire storm in a residential area in the foothills in 1991 that necessitated sudden evacuations of residents along narrow roads.	San Francisco is an example of a major city with many people using mass transit to jobs downtown and major traffic choke points (bridges) for traffic into and out of the city in two directions. The 1989 earthquake demonstrated that damaged bridges and elevated freeways can limit mobility and force people out of their cars. The 1991 wildfire resulted in the evacuation of about 10,000 residents from a foothills residential area, many having to abandon their cars due to the narrow, often blocked roads in the area.

Location	Characteristic of Emergency Evacuation
New York City Example of: A city with a very high percentage of the downtown workforce commuting by mass transit, and emergency events in 2001 (9/11 attack) and 2003 (Northeast blackout) that prompted the sudden departure of workers and others from the business district of Manhattan, in private cars, mass transit, and including tens of thousands of them going on foot for several miles in order to reach homes in other boroughs.	On the morning of 9/11, evacuation of one and then the second of the World Trade Center towers were ordered because of being hit by the hijacked airliners. Many building evacuees and others began to leave the area in cars or on foot. A larger scale evacuation began when the towers collapsed. Large numbers of people left Lower Manhattan on foot, along with vehicle traffic. Bridges and tunnels had to be controlled in order to accommodate the outbound vehicles and pedestrians and inbound emergency vehicles. Ferries and other types of boats were put into service for pedestrians leaving Lower Manhattan. Rail and bus transit functioned beyond the area of the World Trade Center complex. Accounts indicate that many people walked relatively long distances most likely to get to their residences in other boroughs of the city. (More than 50% of downtown workers typically use mass transit to get to work.) In August, 2003, an extensive power outage in the Northeast resulted in workers leaving the office buildings in Manhattan mid-afternoon. Vehicle traffic quickly gridlocked with no traffic control lights and electric-powered mass transit was inoperable. Large numbers of people walked to their residences in other boroughs. Bridges and tunnels were designated to accommodate both vehicle and pedestrian streams; there was no surge of inbound emergency vehicles.
Seattle, WA Example of: The use of a "dirty bomb" scenario for a TOPOFF exercise that would call for the downtown population to shelter-in-place and only evacuate when buses were provided to move that portion of the population likely to be in the radiological plume path to a safer part of the city.	In 2003, Seattle exercised portions of local and state emergency response systems with the scenario of a "dirty bomb" (conventional explosives used to disperse radioactive material) detonated in an area between Interstate-5 through the heart of downtown Seattle and the waterfront. The evacuation plan (simulated) was based on the strategic objective of minimizing the amount of downtown population movement because of the danger and uncertainty of a radiological plume. Vehicle traffic was prohibited. The Ferry Terminal was simulated to be in the path of the plume. The downtown population would be instructed to shelter in place with the exception of those instructed to board buses deployed to move people from the projected path of the plume. Total compliance was assumed for purposes of the exercise.

Although New York City officials have the most relevant experience with pedestrian evacuation, most agency representatives that were contacted declined the invitation to participate because of the high demand for interviews that they have experienced since 9/11. Consequently, some information from other anecdotal and published sources has been included in order to present observations about the evacuations in New York City.

3.2 Findings from Interviews with Practitioners

3.2.1 Washington, D.C., Metropolitan Region

The greater metropolitan region of Washington, D.C., includes the District and parts of the adjacent states of Maryland and Virginia. Although the Pentagon suffered the direct impact of the 9/11 attacks, a much more general evacuation was experienced in the District. Some information is presented here related to the evacuation of the Pentagon, but the interviews with the practitioners focused more on what happened in the District that same day. No interviews were attempted with Pentagon officials or Arlington, VA emergency response agencies.

The crash of the hijacked commercial airliner into the Pentagon on 9/11 represents a “no-notice” event in the Washington, D.C., metropolitan region. By the time this event took place, the major commuter routes in the vicinity of the Pentagon were filled with traffic that was barely moving. This traffic was caused by people who began to leave the District upon hearing about the attacks on the World Trade Center. These traffic conditions did delay some emergency units that deployed to the Pentagon, but no mention has been found that pedestrian traffic interfered with emergency responders.

Many people commute by Metrorail and bus to the Pentagon, which is served by a station under the facility. Metrorail services were programmed to by-pass this station after the Pentagon was hit, but commuter rail and bus services were still available at the next station on the line, which can be reached by a pedestrian underpass. Pentagon evacuees without cars who took this route to find transportation would have avoided the congested roadways. This is an example of how urban planning and design for pedestrian safety and convenience under normal conditions can be of particular benefit to pedestrians in emergency evacuations.

Telephone interviews were conducted with transportation and transit agency representatives for the Washington, D.C., area, and information was obtained during the subsequent project-related workshop. The interviews provided observations related to the sort of spontaneous evacuation that began in the District as people began hearing the news of an airliner hitting a World Trade Center tower. When the second tower was hit in the same way, the evidence that this was an attack and not an accident quickly changed the interpretation of the situation for federal agencies and workers.

The typical high-volume traffic and transit period of the morning commute was nearly over when the traffic began to reverse direction as people in the District began to leave. It became even more pronounced once the Pentagon was hit. The sidewalks and congested streets in some areas filled with people leaving office buildings in large numbers. The assumption is that most people

left for home. At around 10:30 a.m., the Office of Personnel Management notified federal government workers that they could leave work, which further increased the outbound traffic.

No report was found that any kind of a formal recommendation was made by authorities for people to leave the District, but many other pre-planned security arrangements were implemented. Evidence for this is the sudden appearance of physical security perimeters around high-probability target areas like the White House and Capitol area, which forced pedestrians and vehicle traffic to take detours from their usual routes. At least one report states that a recommendation was made to the transit authority that Metrorail services be suspended, but transit officials declined to do so based on their assessment of the nature of the threat and the importance of transit services for people leaving the District. Some route changes were made, including by-passing the stations at the Pentagon and Reagan National Airport. In-bound traffic was deflected in several places. Since no impact area was located in the District itself, there was no major convergence of emergency response personnel to any specific location in the District.

Selected points important for practitioners: The evacuation was spontaneous rather than recommended, causing the traffic control measures to prevent gridlocked traffic to lag behind the initial stages of the evacuation. The large numbers of people leaving office buildings at approximately the same time created even larger crowds on the sidewalks and around mass transit loading areas than does an end-of-day commute. The sudden deployment of security barriers around government facilities created unfamiliar detours for both drivers and pedestrians. Since 9/11, traffic cameras have become more common along major routes, and can be of considerable value in the event of a future evacuation. The transportation agency also intends to continue to deploy "spotters" to watch the evacuation traffic at key points in order to be able to resolve traffic conflicts or delays before they worsen. It is critical for transportation agencies to work closely with the mass media to ensure that no misinformation gets reported about the status of the mass transit system since it can be an important mode for use by evacuees, rail service in particular because it is not affected by traffic congestion.

The summary observations given below provide a few different perspectives, but do not cover all the agencies that were directly involved.

Challenges Described from the Perspective of Traffic Management

- Shortly after the hijacked airliner hit the Pentagon, the downtown area of the District experienced large numbers of pedestrians crowding sidewalks and often spilling into the roadway, where vehicles were gridlocked and at a virtual standstill. It is likely that the pedestrians were people who had used mass transit to get to work and people who knew that the traffic congestion would greatly slow down any effort to leave the District by car. [Note: it is not clear if vehicle traffic could not move at times because pedestrians were in the street, or if pedestrians spilled over into the street because the traffic was at a standstill.]

- The huge number of people leaving the District at the same time that morning is believed to represent voluntary collective behavior mainly on the part of people who worked in the District. Some people started to leave, and soon others made the decision to do the same. At that point, it probably would have been difficult to instruct people to not leave and

would have heightened confusion and stress already evident because of the attacks. [Note: The various motivations for leaving cannot be known from the information available. The situation was ambiguous. The already completed attacks suggested that there might be further targets, and Washington, D.C., is considered a major potential target. One motivating factor cited in disaster research documents is that people tend to seek out family and friends in threatening conditions.]

- At the time of the 9/11 attacks in 2001 there were no traffic cameras at intersections in the District and on-line sources of information were unavailable. The transportation official made a reconnaissance trip to the busiest part of the District to conduct a visual inspection. The first-hand observation of the rapidly developing outbound vehicle traffic gridlock provided information important to the District DOT (DDOT) on which to base decisions about the deployment of their various assets.

- The mass media had wrongly reported that Metrorail was not operating; only two stations were closed for security reasons. This misinformation is thought to have caused many people to ignore the option of Metrorail, which would have provided a faster means of egress from the District than attempting to walk out or to use surface bus transportation. Besides the inconvenience, these slower modes could be regarded as extending an evacuee's exposure to potential risk in the District. Also, these options may have been less familiar to evacuees than their usual commuting mode.

- The surface transit systems of the Maryland and Virginia counties adjoining the District are designed to link with the District Metrorail and Metro bus routes. On 9/11, commuters suddenly started back for the suburbs just at the end of the morning rush hour commute. It was difficult for the surface transit agencies beyond the District to know what to expect in the way of passenger surge, because a situation at the Washington Metropolitan Area Transit Authority (WMATA) Operations Center hindered communications.

- The mass media had wrongly announced that the bridges were closed. The traffic manager reported the vehicle and pedestrian scene along 14th Street as chaotic, with some people behaving aggressively as drivers and pedestrians became annoyed with each other.

- The traffic manager observed that the security perimeters established around such places as the White House and Capitol Hill, and perhaps other federal buildings, served as obstacles to familiar routes, and created longer and unfamiliar routes for pedestrians as well as for vehicles.

- One official stated that Washington, D.C., has to be considered a target for future terrorist acts, and consequently needs to engage in aggressive preparedness activities. It is important to have the capability to move workers and residents out of the District quickly, to reduce exposure to secondary events. The typical week-day commuter traffic congestion illustrates the difficulty of achieving this goal if large numbers of people attempt to use private vehicles.

- The emergence of a "walking event" as a major evacuation mode seemed inevitable, given the number of people who attempted to leave work at about the same time to go

home and the gridlock that developed with the surge of vehicle traffic which was beyond usual rush hour levels.

Challenges Described from the Perspective of the Transit Police

- Many people suddenly wanting to use Metrorail for evacuation didn't seem to have any kind of a personal plan; they seemed to be relying on the authorities to give them explicit guidance.

- Metrorail on a routine day runs near the saturation point. On the morning of 9/11, when people began to evacuate the District, the passenger demand was even higher than normal. This placed extra demands on the transit police to maintain crowd control and passenger safety. On the other hand, since the New York City attack occurred fairly early in the morning, some portion of Washington commuters may have never even started their ride into the District as they monitored the news about New York City.

- One of the two Metrorail stations that were closed due to security reasons also had the largest bus station in association with it. Since passengers had to go on to the next station before leaving the train, the location for the Metro buses that were to connect with the Metrorail had to quickly be re-established at the other station to keep the passengers moving.

Responses or Adjustments Implemented

- On 9/11. Emergency plans developed during preparations for Y2K for traffic management were implemented. The Mayor for the District requested the National Guard be deployed to provide traffic management at the intersections designated in the plan as most critical, so that the police would be free to carry out a broader range of safety and law enforcement activities.

- On 9/11. Metrorail was able easily to extend service at its rush hour capacity (provide more trains with more cars) because the rush hour shift of operators was still in place when the surge of people wanting to leave the District by Metrorail began.

- On 9/11. The Maryland transit agency was able to quickly institute its evening rush hour procedures just at the end of the morning rush hour because buses and operators were still on duty. This capacity was important to have in place to meet the demand of large numbers of passengers that had originated in the District headed for the Maryland residential suburbs.

- Existing Routine Procedure: The transit company can provide "bus bridges" to take care of expected increases in passenger load, and to serve as a substitute for Metrorail services if they are interrupted.

- Post-9/11: Cameras have been installed at many critical intersections in the District which permit the remote assessment of emerging problems with respect to not only vehicles but pedestrians.

- Post-9/11: The traffic management agency has participated with other agencies in efforts to provide information to the public about alternatives to becoming part of the traffic congestion. These include education activities about how to shelter in place, and suggestions like having a pair of walking shoes available if walking home becomes the preferred adjustment to the traffic congestion.

- Post-9/11: The Citizens Emergency Response Teams (CERT) have been engaged to provide public education about evacuation options and the use of the subway, and have been trained on how to assist people with the subway system during an evacuation.

- Post-9/11: The Transit Police work with local police jurisdictions, fire departments, and public works agencies so these personnel will be familiar with Metro stations and procedures in the event of needed emergency assistance to passengers and to the Transit police.

- Post-9/11: Traffic managers still use spotters to go out to see what is happening on evacuation routes, so the District's Traffic Management Center will know about such things as pedestrians on the bridges along with the cars and can decide what to do.

- Post-9/11: A RICCS (Regional Incident Coordination and Communication System) has been developed for the entire region (District, Maryland, Virginia) to provide a central point to which various agencies, including transportation agencies, can direct information about some emerging situation. Posted information can be viewed by other agencies, or conference calls can be arranged among selected agencies. This information dissemination enables a wide array of agencies to have information that might be useful for decisions about adjusting their operations to meet changing conditions. For example, the information that large numbers of people on foot are likely to begin crossing over into an adjoining state could be posted on the RICCS, and then used by transit agencies in the destination jurisdictions to deploy special buses for these pedestrians.

Potential Adjustments Not Yet Implemented

- With the Federal government representing 65% of the work force in the district, it could be useful to get the agencies to work together to work out phased releases of workers to even the flow over a longer time, or, alternatively, to engage in preparations to shelter workers in place. As part of this the Office of Personnel Management (OPM) for federal agencies could develop plans in advance for the message they will give in a similar circumstance and ways to provide guidance for staggering worker release times in order to help distribute the flow of people to the subway more evenly. [Note: Some experts are skeptical that people will comply with a staggered release; others even hold that it is unethical to consider asking people to delay their departure in the face of immediate danger.]

- Consideration needs to be given to the trade-off between slowing the evacuation of tens of thousands of people and the increased security measures that have resulted in a growing number of obstacles (fences and bollards) to evacuation being created by the introduction of security perimeters around Federal buildings.

- Better coordination and quicker decisions about public information messages from across multiple Federal agencies is needed, in order to provide important guidance to pedestrians and other people evacuating.

- In response to a question, the traffic manager didn't think consideration was being given to bike paths as options for pedestrian evacuation, even though he could see how they might be useful as alternative routes for pedestrians.

- The situation that emerged on 9/11 demonstrated the critical role the Metrorail can have in expediting a necessary evacuation of the District. However, the WMATA emergency planners do not assume that Metrorail will be available. Considerable attention is paid in their emergency planning and exercises to the scenario of Metrorail being the target of a terrorist attack. This scenario results in the thousands of riders on the system being evacuated from the trains and out onto the streets, in need of an alternate mode for continuing their evacuation. When some portion of Metrorail is disabled temporarily, buses are put into service to "bridge" the disabled gap in the overall system. However, this alternative would not have adequate capacity in an urgent and large scale evacuation, so WMATA assumes walking will be an important alternative. WMATA emergency preparedness brochures for the public urge transit users to think about walking routes as one of their alternatives in an emergency.

- Even though considerable effort has been made by many agencies to develop a Regional Emergency Coordination Plan, this Plan in its earlier stages did not acknowledge the likely scenario of an evacuation from the District that includes a major "walk out" by people, as an alternative to driving or using mass transit. Recently, the need to include measures for facilitating pedestrian evacuation has been receiving more attention in the District Department of Transportation (DDOT), and in the regional evacuation planning.

- One of the participants in the development of the Washington Metropolitan Regional Emergency Coordination Plan (RERC) believes plans should be made for keeping the walkers and emergency vehicles separated out onto different routes, to prevent the pedestrians from impeding the response. Modeling that has been done of the load likely to be put on the transportation system during a sudden evacuation of the District suggests that many people will resort to walking out so options for designating some roads for evacuation and others for counter-flow of emergency vehicles need to be planned.

- The group that is planning for regional emergency response is considering the inclusion in the plan of sheltering-in-place as an alternative to the evacuation of an area but are not certain what type of a shelter-in-place option people would be likely to comply with given the importance to most of getting to the same location as other family members.

- The Maryland transit official indicated that the transportation planners are considering plans for designating staging areas for transit along the state-District border, in order to have transit available for large numbers of people leaving the district, especially those on foot.

3.2.2 Cleveland, Ohio

An internet search on the topic of pedestrian evacuation identified an evacuation plan for the City of Cleveland that addressed both pedestrian and vehicle evacuation. According to representatives of the Emergency Preparedness Office, this plan had been prepared following the events of September 11, 2001. On that day, as information about the hijackings emerged and it appeared that perhaps one of the planes was headed in the general direction of the city, the mayor ordered the evacuation of the few (six to nine) high-rise office buildings in the downtown area. This evacuation prompted a general, self-initiated, and essentially full-scale evacuation of downtown Cleveland, resulting in considerable traffic congestion. Although additional police officers were dispatched to manage the traffic, it took about ninety minutes for the traffic to clear out of the downtown. The Mayor requested the development of an evacuation plan that could be put into effect to ensure a much more rapid and efficient evacuation of the downtown area, should it become necessary in the future.

Cleveland also was affected by the prolonged Northeast Blackout in August 2003. A high level of traffic congestion ensued when the power outage prompted people to leave offices and stores for home. This was viewed and handled as a heavy outbound commute and not as an evacuation, since there was no urgency to clear the downtown. With the light rail out of service because of the loss of power, the transit authority implemented a contingency plan for replacing the light rail service with surface buses to accommodate those commuters. The interviews highlighted the difference in the concept of operation for an evacuation as detailed in the evacuation plan for the downtown compared to a commuter surge or sports event traffic.

Interviews were conducted with representatives of Cleveland's Emergency Preparedness Office in the Division of Fire, the Division of Police, and the Regional Transit Authority.

> **Selected points important to practitioners:** The evacuation of just a few downtown buildings in the face of a general threat (as happened in Cleveland on 9/11) is likely to prompt evacuation of the entire downtown area so it is important for responders to be prepared to manage it. When the development of a downtown evacuation plan was undertaken shortly after 9/11, the mayor involved the downtown building owners and managers groups as well as public safety and other government agencies. This helps to spread the education efforts among many participants about the evacuation plan. When Cleveland was affected by the northeast blackout of 2003, emergency managers recognized the exodus from downtown as an early commute rather than an evacuation and did not try to invoke the downtown evacuation plan because of its basically different underlying strategy for clearing people from downtown. The normal contingency plans that the transit authority has for quickly creating "bus bridges" if some portion of the rail system becomes inoperable are easy to activate should they be needed to effect some part of a city evacuation.

Challenges Presented by the Events on 9/11

- When the mayor ordered the evacuation of the major high rise buildings, the emergency organization found they did not have pre-established contacts for advising building management of this action.

- Downtown Cleveland is mainly commercial, with a low residential population; only about 4% of persons who come into the city during the day do so on mass transit. The officials interviewed described it as a "car town." Thus, as people made the decision to leave the down town, beginning with those evacuated from the high rise buildings as a precaution, most used a private vehicle. Traffic congestion was considerable and progress slow.

- Cleveland is bordered on the north by Lake Erie, which bars egress to the north, and to the west by the Cuyahoga River; west-bound traffic must be funneled to several bridges.

- During the 9/11 evacuation, an initial order to shut down the rail transit created some confusion among the rail commuters; it was soon determined to have been inappropriate, and rail transportation was restored about an hour later.

- Even though the city agencies are accustomed to the congestion related to events at the Cleveland Browns stadium on the north edge of the downtown, an evacuation of the downtown proper, spontaneous or directed by authorities, was unprecedented and was not directly addressed in the emergency preparedness activities. Thus, various agencies did what seemed right at that moment, but with less than adequate integration of information and coordination.

Responses and Adjustments Made

- On 9/11. Although the recommended evacuation of the high rise office buildings appeared to have been a major impetus for a much larger segment of the downtown worker population to also leave the downtown area, this had not been anticipated. At the same time, nothing threatening had actually happened in Cleveland, so the people leaving did not exhibit any great sense of fear or urgency. Drivers were calm and courteous.

- Post-9/11. A protocol for who decides and who implements any shut-down of any part of the mass transit system has been developed and is part of the emergency plan. The decision will be made at the city's Emergency Operations Center, based on available information about the situation, and with a representative of the Regional Transit Authority present.

- Post-9/11. The emergency management organization has put in place a procedure for alerting the members of the Business Owners and Managers Association about necessary emergency actions so they can relay the information to the business community.

- Evacuation Planning. Public agencies and private organizations were pulled together to develop an evacuation plan for the city. They started by thinking in terms of the evacuation plan taking into consideration four categories: people in cars; people who use public transit; people who walk; and people who live downtown. The panel included the city's public safety agencies, the Greater Cleveland Regional Transportation Authority, the Building Owners and Managers Association, and the Northeast Ohio Area-wide Coordinating Agency which is the metropolitan planning organization (MPO).

- Evacuation Planning. The planning discussions led to a general consensus that the public safety agencies need to be concerned with the big picture of most of the population and not the special needs of various individuals. They feel that the evidence from other situations, such as New York City on 9/11, indicates that individuals having problems will be helped by others as the evacuation takes place.

- Evacuation Planning. The emergency planners believe it is necessary to avoid over-planning, that is, avoid trying to think of every little thing and addressing it. The preferred approach is to lay out and share among the players the basic concept of the response, and then deal with the various unanticipated aspects within that framework as they come up.

- Evacuation Planning. The Cleveland planners did not include the option of sheltering in place as an alternative to evacuation in their plan because several hold the opinion that it is not realistic to think that some people will remain in place, even if recommended to do so, if others are evacuating.

- Evacuation Planning. The officials noted that working on the plan brought together different agencies and groups that had previously had not worked together for emergency planning. Working relationships emerged among agency representatives that are expected to facilitate major emergency response in the future. As one of them put it, if agency representatives already are used to working together, "the people involved are more likely to keep the broad objective in mind when they are working together to respond to an emergency."

- Evacuation Plan Distribution. Citizens have been provided with brochures and web links describing the evacuation plan and providing a map. The downtown is divided into quadrants, each having routes pre-established for moving outward from each part of the business district. If an evacuation is ordered, incoming traffic and cross-town traffic will be prohibited by law enforcement personnel. The plan assumes an evacuation is most likely to be vehicular, although in certain circumstances it may be necessary to leave some areas on foot. For people who evacuate the downtown on foot, the evacuation routes take them to a designated transportation hub within a mile or less, where busses will take them to some further staging area that has necessary amenities. The central concept of the plan is to clear people out of the central area in 30 minutes or less if there is an actual threat, by having them move along a specified direct route from their location to a safe distance. At that point, each evacuee can then make the necessary alterations in route to their home or other preferred destination.

Challenges Presented by the Blackout in 2003

- For the power outage, the plan developed for the evacuation of the downtown area was not used, because the situation did not call for a rapid dispersal of the population for safety reasons. The emergency evacuation plan calls for moving people along specified direct routes to staging areas away from the threatened downtown area; the evacuees then must find their way home from there. The response for the blackout was to facilitate mobility so people could get from downtown to their home or other desired destination

before nightfall. This included the use of the normal contingency plans used by the transit authority for any type of disruption in rail services, such as fires or derailment.

- Because traffic signals were out, law enforcement personnel were dispatched to major intersections to keep traffic moving and thereby minimize the traffic congestion in the city. However, commuters who made their way to one of the freeways then encountered major congestion and slow moving traffic.

- In the power outage, the light rail did not run. However, because the outage began in the late afternoon, the transit system staffing was at rush hour capacity and could be held over to operate the extra buses needed to accommodate the rail commuters.

- The transit authority tracks where every rail car is on the system at all times, and thus could move efficiently to send workers to each car to evacuate the passengers from the stalled trains. They then could dispatch buses to these locations to pick up these passengers and take them to the park-and-ride locations along the rail line.

- As a result of problems encountered with the city's improvised emergency operations center during the blackout, the city built a better equipped Emergency Operations Center.

3.2.3 The San Francisco Bay Area

Interviews were conducted with responder agency officials who had direct experience with two major disasters in the Bay Area—the collapse of a portion of a double-deck highway in Oakland during the Loma Prieta Earthquake in 1989, and the sudden evacuation prompted by the unpredictable behavior of the Oakland/Berkeley Hills Wildfire (also called the Tunnel Fire) in 1991. An interview also was conducted with a representative of the Metropolitan Transportation Council (MTC), the agency that serves as the Metropolitan Planning Organization (MPO) for the Bay Area. This organization has been active in efforts to develop an integrated response among the transportation agencies and in conducting drills and annual exercises to test these plans.

Selected points important for practitioners: Experience with portions of highways being suddenly closed due to earthquake damage has made local authorities aware of the situation of drivers suddenly finding themselves in areas they are totally unfamiliar with and in need of staging areas, service, and information. Media convergence on areas with dramatic damage can create a bigger problem for emergency responders than do pedestrian evacuees who are more likely to stay out of the way. Because earthquakes often cause damage to some parts of the transportation infrastructure, the transportation agency is like to be focused on addressing these problems and not available for assistance with evacuation streams in other locations. The Oakland Hills fire demonstrated that people accustomed to driving out of their neighborhoods may not think to evacuate on foot along footpaths even when that it is evident that driving out will take too long. One law enforcement officer interviewed stated his belief that pedestrians will know what to do and will not need a lot of direct instruction from officials, who can focus on other things.

Challenges Posed by the Collapse of the Cypress Elevated Highway in the Earthquake, 1989

- Uninjured drivers whose cars were trapped in the freeway collapse climbed down from the freeway. They most likely were not familiar with their location and needed to get to a place where they could contact relatives or friends for transportation. One respondent referred to the people who are separated from their vehicles while going from one area to another as "freeway refugees," because they are suddenly in strange territory and need assistance to find certain facilities.

- There were too few neighborhood people or other onlookers at the response scene to have constituted an impediment to emergency vehicles and activities. However, the media quickly converged at the freeway collapse scene with large vehicles and other equipment, blocking the access of emergency responders. [Note: Because the event occurred at the beginning of a World Series game in San Francisco that evening, there was an unusually large contingent of national media in the area.]

Challenges Posed by the Earthquake Damage to the Bay Bridge, 1989

- The earthquake caused a piece of the bridge at mid-span to drop below the road surface. Cars that were on the bridge but not yet past mid-span could not continue across the bridge. One respondent reported that some people abandoned their cars and walked back across the bridge the direction they had come. Another respondent said that eventually a procedure was established for having drivers turn their cars around and drive off the bridge, using the empty lane going the other direction. [Note: It is easy to imagine bridge damage, especially to the bridge approaches, that would necessitate all drivers having to walk off the bridge, leaving their cars stranded. Depending on the situation, emergency responders might need to arrange for transportation for such bridge evacuees.]

- Many workers in downtown San Francisco live in the East Bay area (e.g., Berkeley, Oakland). The type of earthquake damage that occurred to the Bay Bridge eliminated the use of that bridge as either a vehicle or pedestrian route. In this instance, the underground BART system between San Francisco and the East Bay was determined to be operable after initial assessment, so it could be used by commuters going between San Francisco and the East Bay communities. Other bridges that provide the shortest routes between San Francisco and other Bay Area communities were not damaged.

Challenges Posed by the Oakland/Berkeley Hills Fire, 1991

- The residential areas in the Oakland and Berkeley Hills had started out as areas of summer homes, many with small winding driveways to individual houses. This maze of driveways and roads was extended and paved as more and more houses were built in the area. In many instances, groups of houses had only one ingress/egress option. Little attention was given to planning for the evacuation of a large proportion of the residents in the event of a wildland fire in the area. Winding roads that already created challenges for fire fighting equipment with long wheelbases were inadequate for any large surge of two-way traffic. When the fast-moving and unpredictable firestorm enveloped large portions of the area in 1991, the residents had little preparation for evacuation.

- More than 3,300 homes were destroyed by the fire. It is estimated that approximately 10,000 people evacuated their homes during the Oakland Hills fire. Many of the 25 people who died were trying to evacuate. A responder who had been with the Oakland Fire Department at the time described how quickly the situation changed, causing even the firefighters to evacuate the position they had established for fighting the fire. As the fire began spreading in several directions, their role changed from that of firefighter to that of advising residents to evacuate immediately. Thus, a mix of fire department vehicles, residents in cars, and residents on foot all moved together to get away from the hillside neighborhood that was threatened.

- The police chief noted that he had discovered, through the personal experience of his teenage son, that the police had gone through the area in which his home was located to prompt the residents to evacuate because the fire had suddenly started spreading in that direction. The son, home alone and too young to drive, did not have any means other than on foot, to evacuate. The chief has since then taught police officers that when they are advising people to evacuate an area, they need to consider what might need to be done for people who do not have the means to do so. They cannot assume everyone has access to a vehicle.

Adjustments Implemented

- Cypress Freeway collapse: The police called the Transit dispatch center to request buses to take the evacuees from the collapsed freeway to a nearby military facility where they could rest and make telephone calls. This is a standard practice implemented between the police and the transit company whenever buses are suddenly needed at a specific point to move groups of people. [Note: Given the widespread use of cell phones nowadays, people likely will use these to arrange private transportation. However, in order to keep traffic congestion away from the response activities, it may be advisable to establish a staging area where people who have no access to a vehicle can be picked up.]

- Crowd Management—General: The Police Chief noted that he believes people are fairly self-reliant in emergencies and can decide on a course of action without explicit instruction from authorities. Also, the police generally have other things to do besides focus on people on foot in the area. He believes that it is when authorities try to be over-controlling with crowds that it causes trouble. The emergency manager of another Bay Area community echoed these sentiments. In thinking about a scenario of an explosion or other situation requiring the evacuation of 70,000 from the local stadium, he expects that people who do not have vehicles and live elsewhere will likely begin moving toward the BART line; they will not need, nor would they pay much attention to, efforts of officials to specify a route for them to take.

- Mass Transit Characteristics: One respondent noted that in many cities, mass transit is designed to get people from the suburbs to the city center and back. This limits its use for taking people shorter distances in between. Other means of transit will have to be used for that purpose. Planning and exercises for coordinating Bay Area multi-modal transportation providers in emergency and disaster conditions have been carried out for many years, in conjunction with the Department of Transportation and the emergency

management officials. Emergency planning calls for the Metropolitan Transportation Council to compile and disseminate information on mobility options available throughout the Bay Area. However, the observation was made that transportation workers will be concerned with managing their assets, so it will most likely be law enforcement personnel who would manage a pedestrian evacuation, should that emerge, for example, if the subway had to be evacuated.

- Short-term Evacuee Needs: One respondent observed that, in his community, specific locations have been pre-designated as short-term shelters that can be used in the event that people have to be evacuated from an area because of a hazardous materials spill, toxic release, or fire danger. He thinks these shelters could also be opened when people are evacuating on foot away from the freeway because of freeway closure due to damage such as overpasses collapsing in an earthquake.

Adjustments Planned for Future Implementation

- In the course of a hypothetical discussion of alternative modes for evacuation from San Francisco, the San Francisco respondents note that the several ferry routes between San Francisco and other points offer an important alternative mode for pedestrian evacuation, should one or more of the bridges be closed. The ferry system is characterized by a great deal of flexibility. There are docks in many places for loading and unloading, and most ferries also can be accessed from simple docks quickly set up for that purpose. The ferry system can be called into service for evacuation.

- Because of the similarity of the Berkeley Hills residential area to the area affected in the Oakland Hills Fire, the emergency manager of Berkeley wants to improve existing pathways between houses and link portions of circuitous roadways in order to provide alternative routes for pedestrian evacuation. These walkway rights-of-way are considered the property of the city. The narrow roadways in the residential area can become clogged with traffic or a roadway might suddenly become cut off by the fire, making the use of a vehicle for quick evacuation problematic. He has been able to obtain a Federal Emergency Management Agency/Department of Homeland Security (FEMA/DHS) Fire Prevention and Safety Grant to use for this purpose, illustrating the need for creative thinking about the dual use of various grant programs related to emergency response and response safety. The project activities funded by the grant will be carried out in conjunction with the activities of a volunteer group working on enhancing the walkways for recreational uses.

3.2.4 New York City Region

The events of September 11, 2001, when terrorist-controlled airliners were flown into the World Trade Center towers in a major business district of a large metropolitan area, present perhaps the most basic scenario for conditions likely to result in a large-scale pedestrian evacuation. Although city officials declined to provide interviews for the research, a general description can be pieced together with information from news accounts, news photos, and various research reports. This decidedly threatening event occurred with no warning. It also occurred in two stages—the impact of the planes on each of the towers, and then the collapse of each tower.

People who evacuated from each tower after it was hit apparently arrived at the street in a fairly steady stream, most not even aware of exactly what had happened to the building. Some needed medical attention; others apparently dispersed in various directions on foot or initially lingered in the general vicinity as observers. Initially, no other buildings were evacuated.

On a typical work day a large proportion of the worker population present in lower Manhattan that morning will have arrived there by mass transit rather than by private vehicle. Soon after the initial attack, the subway was shut down and passengers were evacuated from it. All traffic inbound to Manhattan was prohibited, with the exception of emergency response vehicles. The compactness of the Borough of Manhattan, joined to the more residential boroughs by bridges, tunnels, and ferries, made feasible a decision to head out on foot for other parts of the city. Buses had continued to run and by afternoon subway operations were re-established in areas other than Lower Manhattan. Given that Manhattan is an island, all routes for leaving the island represented major choke points for both vehicle and pedestrian traffic.

Street access to the immediate area around the WTC had quickly been closed off by law enforcement for all but emergency response vehicles. One report stated that the evacuees from the towers and other observers who lingered around the scene early on stayed out of the way of the emergency responders. The initial exodus from the area of the two WTC towers was characterized by people emerging from the buildings in a continuous stream after an arduous building evacuation experience, walking away from the area, and then running for safety as the first tower unexpectedly collapsed. Within the cordoned-off area the pedestrians spread out across the sidewalks and street in an apparent effort to accommodate individual walking rates. The pressure wave from the collapse knocked pedestrians to the ground, and the dust cloud made it too dark to see for some period of time. Many crouched along buildings or cars, or were pulled inside buildings by other people. After the dust clouds cleared people continued their efforts to get home.

Once these pedestrians proceeded some distance from the impact site, they settled into streams of pedestrians heading toward their destinations of choice. For the most part, these were people who had left their place of work and were headed for home. This situation is essentially the reverse of what happens during hurricane evacuations, where entire families are leaving their homes, headed for some safer place to stay temporarily until the storm is over. Accounts indicate that some degree of official management may have been used to contain these streams so that usually at least one lane was available for emergency vehicles, both on the surface streets and the bridges. As pedestrians reached areas farther north of Canal Street, they encountered the normal mix of activities of people in areas that were not directly affected by the damage. Evacuees, themselves covered with dust from the collapse of the towers, remarked on how strange it was to find other parts of the city going about normal activities.

At about 11:00 a.m., after the collapse of both towers, the Mayor urged that everyone who was still south of Canal Street should evacuate that area. Evacuation in this instance was viewed as a general protective action, given the uncertainty about conditions associated with the destroyed towers. This secondary evacuation involved a heavy stream of private cars; the traffic flowed smoothly and as directed by law enforcement, who had received prior notice that it was to occur.

A no-notice emergency urban evacuation on the scale of that associated with the attack on the WTC towers was an unprecedented event in the United States. Interest in all aspects of the event was intense on the part of the media, criminal investigators, forensic engineers, building evacuation experts, behavioral researchers, and any number of other types of experts. In August 2003, the Northeast Blackout in August prompted another evacuation from the office buildings in Manhattan to other parts of the city by people on foot. Many also had to be evacuated from the stalled subway system. Increased bus and ferry service was fairly quickly implemented to accommodate the demand. Many people chose to walk, and bridge routes were provided for those headed to the east. Lessons from 9/11 led to the implementation of measures to separate pedestrians and vehicles by assigning them to different bridges and tunnels.

Selected points important for practitioners: The large number of people who left the downtown area on foot in the face of the attack on and collapse of the World Trade Towers on 9/11 may be a reflection of the fairly large percentage of people who use mass transit to get to work in the business district so are car-less when downtown. The importance of maintaining mass transit as much as possible, and devising means for providing information to people wanting to use mass transit for evacuation, is critical in this situation. The fact that so many of the people who evacuated on foot walked much further than was necessary to be out of any danger, suggests that when people evacuate from their offices they are most likely to be determined to get home so response organizations need to prepare to accommodate this behavior and make it safer and easier. Many ad hoc arrangements were made to accommodate evacuees such as other boats engaging in ferrying people off Manhattan Island, and law enforcement requesting drivers to take as passengers evacuees who might otherwise try to walk across a bridge or through a tunnel to leave Manhattan. Much of what initially looked like pedestrian evacuation was like to be more multi-modal in that many people walked to where they could get mass transit and completed part of their journey in that manner.

Challenge to the Transit System

One interview was conducted with a representative of a transit agency. This interview served to provide further evidence about pedestrian evacuation as a multi-modal alternative, unless the distance people need to move to be safe is short and the time they need to remain there is brief. Urban transit systems, especially rail systems, can provide alternative evacuation routes to avoid traffic gridlock and endangering pedestrians. However, urban transit systems must address certain challenges.

- The NYC subway system has a clear policy and procedures for evacuating individual trains or all trains in the system. Whenever a train is stopped for whatever reason, including such things as power failures, chemical releases, or fires, anywhere other than a station, the Fire Department or transit operational personnel assist passengers to walk out to the nearest station because of the danger represented by the "hot" third rail. The focus is on achieving a safe and orderly evacuation of the passengers and minimizing damage to the system.

- On 9/11. The transit authority initially focused on security because of the uncertainty about the scope of the attack. After the first tower was hit, the transit authority focused on

evacuating the entire subway system in order to secure it from a potential attack. There was no specific plan in place at the time to provide information or alternate transit for the evacuated passengers or persons arriving at stations in hopes of taking the subway.

- Immediately following the impact of the airliners, buses continued to run except in the vicinity of the WTC. However, there were not enough buses to handle the people evacuated from the subway. This added to the volume of people on the streets who were evacuating from the area of the WTC complex.

Responses and Adjustments Made

- On 9/11. The Subway Control Center was able to use its communications system and procedures to evacuate the subway system. Once the extent of the attack became clear, the Control Center was able to communicate with transit personnel to put the subway system back into operation, bypassing the area of the WTC. Buses had continued to operate, with some alteration in routes around the WTC.

- During the 2003 Blackout, the backup power for the Subway Control Center and communication functions was operable, so trains could be located and the evacuation of the system carried out smoothly. Subway service could not be re-established until power was again available.

- One reason given for the good response of the transit system was the fact that the transit agency's emergency procedures include a comprehensive and up-to-date list of contacts in various agencies. This helped establish direct access to people in a position to provide reliable information and to commit resources during an emergency.

- The transit agency official observed that a greater number of people walked sizeable distances to their preferred destination during the 2003 blackout than during the evacuation from the WTC attack on 9/11, presumably because fewer options for transportation were available during total blackout conditions.

- Post-9/11. The NYC Transit agency has adopted a policy of preparing all operations and administrative personnel to be involved in subway evacuations in order to offer better assistance to passengers. While the operations personnel work with the system, office personnel can be deployed to provide direction and assistance to the passengers emerging from the stations. This can be particularly useful for those passengers who find themselves in an unfamiliar part of the city due to the sudden evacuation of the system.

As was indicated in the earlier literature review, several observations about adjustments made to accommodate the unusually large numbers of pedestrians were gathered during the interviews for the FHWA-sponsored case study of the transportation challenges and responses in conjunction with the WTC attack on 9/11. A major concern of the transportation officials was that the congestion on the bridges associated with having large numbers of pedestrians on the bridges as well as cars might hinder incoming emergency vehicles. Recommendations were developed for ways to keep pedestrians and vehicles separated, such as assigning certain roads and bridges only to vehicles and others to pedestrians, or gathering pedestrians in staging areas where they would be provided bus transportation for crossing the bridges.

Anecdotal Information from First Hand Evacuation Observations

The evacuation situation on September 11, 2001 can be pieced together relatively well from news stories and photographs. Personal web logs on the internet provide another interesting, albeit anecdotal, source of information on the situation encountered by people walking out of the WTC area, their protective actions, and their strategies for getting home. Some insights into the options people had and used can be gleaned from these first hand observations.

- A person leaving the first tower that was struck was directed by law enforcement to 'walk north to the train station.'
- When the tower collapsed, the force of the cloud of dust and debris pushed people off their feet and to the ground.
- The dust was so dark and thick, people thought they might have been blinded.
- When people who were walking away from the scene were caught by the dust-laden pressure wave from the building collapse, they took refuge in doorways and shops or were pulled into these places by others inside.
- A person who had reached the Wall Street area was directed by a police officer to walk toward South Street Seaport and go over the Brooklyn Bridge, at which point she would be transported across the river to Liberty State Park. When she arrived there, she was bused to Penn Station in Newark. Hazmat teams decontaminating people coming from New York confiscated her clothes, shoes, and purse, showered her, checked her vital signs and provided her with hospital scrubs to go home in. Relatives she had been keeping contact with by cell phone picked her up there.
- After the first plane hit, the situation seemed surreal to one observer, who was in the lobby of one of the towers at this time. This person describes himself as going into a sort of survival mode, and going out into the street where he just kept walking, telling himself that he had to get out of the city. He walked south from the WTC, then east to Broadway, and then north. At the Christopher Street Port Authority (PATH) station he got a train to Hoboken where his car was parked, and from there he drove home.

3.2.5 Seattle, Washington

In 2003, Seattle was one of the locations for the TOPOFF-2 exercise. The scenario for Seattle included a dirty bomb explosion in the downtown area. An interview was conducted with a representative of Seattle Emergency Services to determine what sort of protective action was included in the exercise scenario for an event that involved a radioactive plume associated with the destructive explosion of a "dirty bomb."

Challenges Described

- The exercise scenario involved the explosion of a dirty bomb at the south end of downtown Seattle, less than a mile from Interstate-5. The emergency response entailed making an assessment of the situation before deciding on appropriate protective actions

for the public. For the TOPOFF-2 exercise, Interstate-5 through downtown Seattle was closed, presumably as a precaution to avoid exposure of travelers. The downtown Washington State Ferry Terminal was not accessible because it was located in the projected plume path from where the bomb exploded.

- In response to a question about the experience of congestion around a response scene that hindered access by emergency responders, the respondent recalled an incident where a bus went off the edge of a bridge when a passenger shot the driver. The Fire Department and EMS responders were unable to get in good position to respond because of the police cars that had converged on the scene. He recalled that the same thing had occurred at the collapse of the Skybridge at a Hyatt Regency Hotel. The police had converged at the scene, and left their cars parked and locked in the circular drive in front of the hotel when they went into the hotel, thereby hindering access by other emergency responders.

Adjustments Assumed in the Simulation

- For the dirty bomb scenario, the emergency managers ordered (in simulation) the public in the metropolitan area to shelter in place, in appropriate areas of their offices and residences. The public was expected to remain sheltered in place unless the incident commander ordered people to be moved from an area where the radiation was expected to intensify as the plume from the explosion moved across the city, depending on the wind currents. The logistics for moving people, mainly by bus, would be implemented from the Emergency Operations Center. The public was ordered not to use vehicles to evacuate, but rather to wait to be evacuated by bus to an area not likely to be downwind from the bomb site. In such a situation, some might leave the area on foot instead. [The public was not actually participating.] The response objective was to minimize population exposure to the radioactive plume by moving only those persons who might otherwise be in its direct path. The hazard zone was being determined on an ongoing basis by plume modeling experts.

- The emergency services department holds that it is not appropriate to predetermine specific evacuation routes, because the location and nature of the event are seldom known in advance. Emergency management officials, however, will be aware of the most reasonable alternative routes and transportation modes as well as which agencies will help implement an evacuation using these routes. The Ferry system is one of the options to be considered if movement to the west is appropriate.

Adjustments Planned for Future Implementation

- A warning system that the City is putting in place along the Seattle waterfront was described during the interview. It will be used to warn people in the area if sensors have detected a chemical or biological hazard, or, for example, the threat of a tsunami. For many months of the year, this waterfront area is crowded with tourists and other pedestrians making use of the waterfront shops, restaurants, and tour boats. This warning system will have to be accompanied with signage and other public education approaches, so people will know what to do if the warning system is activated. [Note: The waterfront area lies between the water and a steep hill or high rise housing, which limits the options for easy evacuation.]

3.2.6 Observations from a Regional Planner

Selected points important for practitioners: It is important for planners and community officials to keep separate the concepts of temporary emergency evacuation as a protective action and the older civil defense concept of re-settlement of populations away from what are considered particularly vulnerable locations. It is critical for adjacent jurisdictions to engage in integrated planning for many aspects of evacuation including seamless transit service and sharing of information about evacuation routes because evacuees in metropolitan areas are likely to cross one or more jurisdictions.

One respondent, affiliated with a regional planning organization, requested that remarks made during the interview be anonymous. The planner talked broadly about evacuation in general. He made the important point that plans for evacuations where evacuees will be crossing from one jurisdiction to another will have to address many important issues. These need to be worked out in advance. His observations were borne out in at least one incident from the Hurricane Katrina evacuations in 2005 when a group of evacuees were stopped from crossing the boundary into a particular jurisdiction by law enforcement authorities, apparently at the request of elected officials. The planner's observations included the following points:

- Planning for an evacuation of persons that involves moving from one jurisdiction into another can be a sensitive issue to the public. Evacuation planning policy needs to be dealt with by statutorily responsible agencies and not planning bodies. One issue has to do with an evacuation that may result in one jurisdiction becoming a host for the evacuees of another jurisdiction in the event of a long term evacuation.

- Specifying the destination of an evacuation is not a traffic engineering issue; it is a political issue.

- "Evacuation" can be a confusing term because it is a layperson's term. When considering planning assumptions in reference to evacuation, it is necessary to clarify whether the objective is traffic management in emergencies or protective action for the public.

- The planner suspects that what prompts the evacuation makes a difference, e.g., whether it is a response to terrorist or military action or to some more common event, like a hurricane or flood. The specific threat or hazard may determine the use of particular options.

4 IDENTIFICATION OF VARIABLES AND CONCEPTS

4.1 Evacuation Context and Management

Using the information from the literature review and the interviews, concepts and practices that would be useful in planning and managing metropolitan evacuations were delineated. Once the various contextual elements of a metropolitan evacuation are established, the planning effort can focus on the combination of response elements that are bested suited to structural and situational aspects of the specific event and the area affected by it. Basic variables that combine to affect the evacuation process, and which form the basis for planning and managing a no-notice urban evacuation, include the following:

The context for the evacuation varies in terms of:

- Characteristics and geographic scope of the threat to personal safety,
- Location and number of evacuees,
- Configuration and capacity of evacuation routes and mass transit systems,

Evacuation management variables include:

- Strategic intent of evacuation implementation (e.g., minimize vehicle traffic; maximize evacuees going north, etc.).
- Primary evacuation instructions as formulated by the authorities.
- Available options for communicating instructions to evacuees.

The conversations with practitioners and subject matter experts emphasized the distinction between what is managed as an emergency evacuation (primary goal of getting people moved quickly and directly away from a danger area) and an unusually heavily and simultaneous surge of commuters outside of normal rush hour periods. Although the latter situation is by definition unexpected and creates special demands on transportation, public safety, and emergency response personnel, it does not require intervention in destination choices.

As a starting point, it is easiest to think about an evacuation situation in terms of a best case situation. For example, one in which the scope of the impacted area is relative small, the impact moment is past and believed to be over, the weather is mild, it is daytime, transportation modes and routes are similar to normal circumstances, and the transportation and public safety agencies are prepared to work together effectively.

In order to conceptualize approaches for managing large numbers of people leaving the impact area on foot as part of the evacuation plan of a metropolitan area, it is necessary to start by assuming the best case situation. As any transportation or public safety official knows, real events and exercise scenarios introduce variables into this basic scenario that necessitate adaptations to the best-case situation to use as a stating point. Based on observations from the practitioner interviews, case studies of evacuations by disaster researchers, and some degree of logical thinking, such variables are outlined below. There obviously can be multiple combinations variables related to the type of event, characteristic and current conditions of the area, transportation and routing alternatives, whether evacuees are leaving home or going home,

and the degree of preparedness and cooperation among the agencies involved in facilitating the evacuation.

While the following sets of variables are not necessarily exhaustive, they are introduced here to provide an idea of variables related to planning and implementing an evacuation involving a large number of pedestrians. In Chapter 5, several conceptual approaches for managing or accommodating evacuees other than those who are driving or riding in a private vehicle are presented. For simplicity's sake, these are predicated on the existence of the basic, stripped down scenario of a completed impact in a downtown district that is mostly office buildings, during good weather conditions, and in a city with mass transit options.

The base scenario can be affected by variations in the impact situation, the operating principles of the response and management agencies, the characteristics of the population that will be evacuating, and the array of routes and transportation modes that can be safely used for the evacuation. Following are sets of variables for each of these aspects, for the purposes of developing planning assumptions for a particular urban location.

4.1.1 Variables in the Event Situation and Volume of Evacuees

The characteristic of the threat to personal safety is one of the following. This determines the degree of urgency for evacuation, and whether evacuation direction must be controlled.

(1) Impact period is over and effects are localized at point of initial impact.
(2) Impact period is over, but secondary effects are spreading away from initial point of impact.
(3) There is uncertainty about whether impact phase over.
(4) There is no specific impact, but there is concern for safety due to indeterminate threat.

Origin of the anticipated evacuation stream is characterized by one of the following, which determines the number of people emerging simultaneously onto the street:

(1) Origin is restricted to one place of work.
(2) Origin extends across multiple places of work in the same area.
(3) Origin is mainly residential in nature, so evacuees leaving home.

4.1.2 Evacuation Management Assumptions and Strategies

Primary belief of officials (e.g., law enforcement) directing and managing an urban evacuation that involves large numbers of people on foot as well as in vehicles can make a difference. Expectations about evacuation or social behavior may affect what type of actions officials take toward pedestrian evacuees.

(1) Pedestrian Evacuees must be told what to do so they don't engage in counterproductive actions that further endanger themselves and others. Or,
(2) Pedestrian Evacuees want information on what to do, at least initially, because they will be uncertain or confused by not knowing what has happened and delay departure. Or,
(3) Pedestrian Evacuees can figure things out given adequate information on the circumstances; agency officials will focus on responding to problems as they occur.

The priority evacuation strategy as established by authorities might be one or more of the following. This is the basis for the type of information and instructions given and how public safety and transportation personnel are deployed.

(1) Get people to move away as quickly as possible, even a short distance.
(2) Get people to move a certain minimum distance away from the impact or threat.
(3) Get people to move in a certain general direction to avoid a moving threat.
(4) Get people to go along a specific route and avoid other routes.
(5) Get people to shelter in place rather than evacuate.

4.2 Multi-Disciplinary Panel Discussion

> A major recurring theme during the discussions of the expert panel was that best practice for managing pedestrian evacuees lies with the application of best practice in overall emergency preparedness and response. For most the emergence of a large contingent of evacuees on foot was viewed as a circumstance that may or may not emerge in conjunction with an urban evacuation. The most important factor for effective management of that variable is that all relevant agencies have a shared understanding of the concept of operations for the jurisdiction's agencies and have established working relationships with other agencies either during actual response activities or preparedness activities such as evacuation planning and emergency exercise.

A list of considerations such as in the previous section was provided to a multidisciplinary panel that was formed to discuss pedestrian evacuation as a concept and as an evacuation scenario. The panel participants included eight practitioners and subject matter experts representing expertise in fire fighting and incident command, evacuation planning, public safety and law enforcement, traffic operations, modeling of pedestrian movement, and social science research on evacuation and disaster response. Many of the participants were from agencies located in the Washington, D.C., metropolitan area, and were particularly sensitive to past experience and special issues related to evacuation in that area. The panel discussed a large number of topics and identified gaps in knowledge and areas in which concepts from one discipline could be transferred to another. A major recurring theme was that best practice for managing pedestrian evacuees lies with the application of best practice in overall emergency preparedness and response. The following points were discussed in detail.

4.2.1 Ability to Adapt General Response Concepts to Specific Events

From the perspective of most of the panel, pedestrian evacuees are considered to be one element that may or may not emerge in conjunction with an emergency event. When engaging in "all hazards" planning, the basic approach is to have all relevant agencies understand the overall concept of operations for an integrated interagency response operation. It is not possible to plan for specific configurations of the event and the city characteristics, so it is critical that agency personnel be able to adapt management and response concepts to be appropriate to particular situations and to know what to expect of each other.

4.2.2 City Characteristics and Planning for Pedestrians in Emergencies

The panel participants identified a few characteristics of a city that probably increase the importance of being prepared to manage pedestrians in an evacuation. These include the extent to which commuters to the downtown area use mass transit, the proximity of transit options to office complexes, and the extent of tourism. These are the factors that are associated with the presence of larger numbers of people unfamiliar with facilities and routes.

4.2.3 Facilitation of Decision Making by Pedestrian Evacuees

Safety is the highest priority when managing pedestrian evacuees. Pedestrian evacuees can make good decisions related to evacuation, even in no-notice events. To assist pedestrians in making choices that are consistent with smart and safe behavior while evacuating, responders and emergency managers must strive to provide consistent and clear information, enabling evacuees to make decisions about the best evacuation mode and route for them.

4.2.4 Multi-Jurisdictional Planning

The history of city growth and residential patterns in the U.S. means that the major metropolitan areas include many jurisdictions, including both local and state jurisdictions and multi-agency planning bodies. If evacuation routes leading out of the central downtown area cross jurisdictional boundaries, planning and practicing for handing off functions to counterpart agencies in the adjoining jurisdiction is crucial. For example, if evacuees not using a private vehicle use mass transit in an evacuation that takes them away from their normal destination, they may not know how to transfer over to the connecting transit system. Coordination between different transit agencies can keep evacuees from becoming stranded at the end of the line of their initial transit ride.

4.2.5 Elaboration of the Role of the Transportation Agency

Transportation agencies have begun to play much more active roles in emergency planning and response. In cities where Intelligent Transportation System (ITS) assets are well developed, the traffic operations personnel will have some of the best information and broadest overview about traffic and pedestrian flow. Transit operations personnel have the best knowledge of the location of transit facilities and assets, and the authority to deploy them. Transportation officials should be considered key players in emergency planning and response, and not simply as a support agency that responds to requests from the emergency manager during the course of an incident or response operation.

5 APPROACHES TO MANAGING PEDESTRIAN EVACUATION

This chapter presents three approaches for transportation and emergency planners to consider in preparation for short term evacuation of part of a metropolitan area in response to an unanticipated harmful event. Here evacuation is treated as a temporary protective action. The assumption behind these approaches is based on the observations from New York City and Washington D.C. on September 11, 2001 that if a large magnitude harmful event prompts the evacuation of a portion of a densely developed downtown area the evacuation streams may include a large number of people on foot. The type of event visualized is that which occurs without notice; that is, without a long enough warning period to permit public safety and emergency response personnel to stage their resources in anticipation of an evacuation and for the downtown population to make preparations.

5.1 No-Notice Urban Evacuation

People may begin evacuating while the public safety and transportation authorities are still activating additional assets to manage the evacuation. People who are already in a private vehicle, along with those who can access their vehicle quickly, will create a sudden surge of vehicles. The tens of thousands of people exiting from the large downtown buildings in a relatively short time period likewise will create a large mass of pedestrians. The uncertainty accompanying the event, along with the disruption of the normal use of a given area, can be expected to create a brief period of seemingly chaotic behavior which then gives way into more purposive actions that will result in evacuees moving away from the area defined as dangerous. Law enforcement and transportation assets can be used to maintain a corridor through the city streets for the use of emergency responders going toward the dangerous area, prevent more people from entering the dangerous area, and enhance the mobility of the evacuees.

As described in Chapter 2, pedestrians apparently have not been an appreciable part of past evacuations in the U.S., unless they simply have been ignored in descriptions of evacuations predominantly characterized by the use of private vehicles. Much of the research on emergency response has focused on public response to warnings and what goes on around the event scene or in the command posts and emergency operations centers. Research on transportation tends to focus on the management of vehicle traffic. Transportation emergency planners recently have begun asking themselves if a large number of pedestrian evacuees are liable to have an impact on vehicle traffic flow, possibly jeopardizing their own safety in the process. Pedestrians, for better or worse, have far greater flexibility for choosing their route and expediting their evacuation than do drivers. This capability provides pedestrian evacuees with the potential for mingling with the traffic or interfering with the activities of responders while they pursue their collective objective of moving away from the dangerous zone.

For the sake of simplicity the most basic no-notice evacuation situation is used as the context for the discussion of evacuation. This is the situation of (1) a damaging event for which the impact has already occurred rather than being a threat with uncertain location and timing, and (2) which is assumed to be limited to the time and place of the initial point or points of impact; that is, there is not a plume of some dangerous material moving away from the point of impact. Other variables include time of day and weather conditions. We recognize that myriad permutations of

these variables are possible which will alter basic planning assumptions for preparedness and the decisions made during actual response operations. All three approaches assume there will be appreciable numbers of pedestrians among the population making a temporary evacuation away from an unanticipated and major impact in the densely developed downtown area of a large city. The reader should consider this as mainly an assumption rather than something inevitable, there having been too few such events in large U.S. cities to know if the street scenes from the 9/11 attacks in New York City and Washington, D.C., are typical for those cities, or if they are likely to occur in other large U.S. cities.

The approaches outlined here are based on information from the review of the literature, ideas from anecdotal accounts of evacuations, and the views of practitioners and subject matter experts carried out as a preliminary inquiry into the topic. This is coupled with the research literature on social behavior in emergency situations and observations about transportation agency practices already used for accommodating large numbers of commuters or attendees at large public events in cities. At this time there is little systematic empirical data about the extent to which pedestrians might hinder the actions of drivers during evacuations, which of their actions are the most troublesome to response operations, and the extent to which they are responsive to instructions from authorities during an evacuation.

5.2 Assumptions about Urban Evacuation Behavior

5.2.1 Driving, Riding, and Walking as Evacuation Options

The three general modes available to individuals whether they are commuting from home to work or going about a city for errands or social engagements are: driving a private vehicle; riding in a private vehicle or public transit; or walking. People who are car-less in a large city normally have several options for making trips within the city or back and forth between home and work. These typically include one or more modes of public mass transit, and also taxis, specialized paratransit services, job-related shuttle buses, chartered or rented transportation for special purposes, and so forth. Many urban dwellers and workers also walk inform place to place in the compact downtown areas of large cities. As one reason, walking can provide more direct routes to nearby destinations than does mass transit, and others including that walking can be faster when vehicle traffic is slowed by congestion or that walking is enjoyable. All of these modes are suitable to use in situations that might prompt a temporary evacuation of a portion of a city. In densely developed urban areas evacuation in one's private vehicle may not be the most effective for making a rapid evacuation. Under certain circumstances, greater use of other modes may be more suitable for achieving a balance of rapidity and safety for the largest number of people.

The penchant to stay with the familiar, the habitual, is characteristic behavior in many types of situations. Research into disasters and evacuations indicates it persists in emergency situations. Thus, some hunches are possible about U.S. urban evacuation behavior. In evacuation situations a preference for what is familiar contributes to that typically substantial proportion of the population that decides to stay put, even when warned of imminent danger, like a hurricane or flood. Most people who evacuate prefer to do so in private vehicles, if they have access to one. The workers who took mass transit to work won't have a car in the city if an evacuation is ordered. Since they are already familiar with using mass transit to go home they are likely to consider that mode first. Evacuees whose choice is a regularly scheduled bus are likely to find

themselves caught in heavy traffic congestion along with the evacuees in private cars. Rail transit can move large numbers of people quickly because it is usually grade-separated from road traffic. Workers in the downtown area who live outside the city are likely to want to go home, and so will readily evacuate the downtown area by whatever means. If necessary, they will walk. People who live in the area being evacuated, if they leave will go to the homes of relatives or friends if possible, rather than to the designated emergency shelters.

It seems safe to surmise that a large proportion of the masses of pedestrians captured in media photos leaving New York City and Washington, D.C., on 9/11 were motivated by the desire to get home. Family members tend to seek out each other under threatening circumstances. The evacuees appeared to be walking much further than was necessary to reach a safe part of the city. The exodus from New York City's Borough of Manhattan during the power blackout across the Northeast U.S. in 2003 probably brought even more people onto the streets on foot because much of the mass transit system was disabled due to the lack of electricity. Most were on their way home from their place of work. In both cases the unanticipated event meant that public safety and transportation agencies were not appropriately deployed in advance in order to mitigate the initial problems caused by the sudden surge of traffic out of the city. In some places the pedestrians made their way through the congested and gridlocked traffic in a manner that alarmed transportation managers who view it as important to keep pedestrians off roadways both because they might impede emergency vehicles or the evacuation traffic and at the same time jeopardize their own safety.

5.2.2 Reducing Pedestrian Evacuation as a Safety Strategy

The observations from the evacuations during the 9/11 attacks and the 2003 blackout indicate that large numbers of people evacuated from the Lower Manhattan area on foot as well as in personal vehicles. The large numbers of pedestrians in the evacuee stream may be an artifact of the high use of mass transit for commuting—53% in Manhattan and 33% in Washington, D.C. During the evacuation of downtown Cleveland on 9/11, when there was a possibility that a hijacked plane was headed that way, there was no noticeable pedestrian evacuation. People went to their cars, joined the rush-hour like traffic, and made an orderly if slow departure from downtown Cleveland. Compared to Manhattan and Washington, D.C., normally a relatively small proportion of Cleveland commuter trips are made on public transportation (12%). There was no mention of a much larger volume of people using public transportation when people began to leave downtown Cleveland on 9/11. This could be attributed, at last partially, to the fact that there was no real urgency and no damage that made it impossible for people to retrieve their cars.

In New York City and Washington, DC on 9/11, not all people who started out the evacuation as pedestrians completed their journey on foot. From anecdotal accounts and observations by transit officials many evacuees who started out on foot took advantage of some mode of public transport somewhere along the way. For example, they may have chosen their pedestrian route so they would arrive at a subway station, bus stop, or a ferry dock. Or as they walked, they may have noticed that the train or bus was an option. Some may have been offered rides by people evacuating in their personal vehicle. Both the traffic and transit managers are likely to be of the opinion that the pedestrian evacuees who switched to mass transit along the way enhanced their own safety and may have reached their preferred destination more quickly.

This suggests two overarching concepts for managing pedestrian evacuees. One is to determine the ways, if any, that evacuations involving large numbers of evacuees on foot as well as in vehicles call for special measures compared to the more commonly observed evacuation in the family car. One special measure that planners are considering is that of keeping vehicles and pedestrians separated as much as possible during the evacuation. Another is to apply traffic and pedestrian management techniques that result in reducing the number of evacuees on foot. The rationale for this is that pedestrian evacuees can avoid some of the hazards they might experience if they are accommodated through the provision of dedicated mass transit that can move them away from the dangerous area and well into the part of the city that was not directly affected. There the evacuees can engage in their usual and familiar actions for getting a ride from a relative or friend to their home, if they evacuated from their place of work in the city. Or they can find alternate lodging if they evacuated from their residence in the city. Two approaches related to this concept are presented here.

Moving a portion of the pedestrian evacuees onto buses or trains, besides removing them from vying with vehicle traffic for access to constrictions in evacuation routes (e.g., bridges or tunnels), can result in moving more of these car-less evacuees faster. And if not faster, the evacuees can proceed at least with less exposure to conditions created, for example, by extreme weather or a nighttime evacuation. For evacuees with poor health or a low level of fitness, the availability of a ride can make the evacuation trip faster and mitigate potential health consequences and injury from walking an appreciable distance.

Given the typical traffic congestion that occurs with a metropolitan emergency evacuation, commuter rail has the potential to be the fastest evacuation mode. To be an effective option, the commuter rail system must remain operational, at least along crucial portions of it, and not be subject to further threat related to the cause of the emergency evacuation. Security precautions may lead transportation authorities and emergency managers to suspend subway operation immediately, although trains might be put back in service after further threat assessment. Given the potential for subway and other rail transportation to expedite evacuation of large numbers of people, the benefit of keeping mass transit running to quickly move large numbers of people away from the evacuation zone may outweigh the level of risk, actual or perceived, associated with a highly uncertain event.

Commuter buses may also serve a role in pedestrian evacuation, but this is more problematic than rail if buses must use the same routes that other vehicles use to leave the city. Buses that follow their normal routes as an emergency evacuation begins will be subject to the same major traffic congestion and curtailed mobility as the private vehicle traffic. Even if normal bus stops and routes are still in effect, there will be no way for potential riders to predict when—or if—buses will arrive. Many people will prefer to keep walking, while others will endure long waits. Situations that delay pedestrians leaving the dangerous area leave them exposed to potential harm for longer periods of time.

5.3 Three Approaches for Managing Pedestrian Evacuation

Three approaches for managing pedestrian evacuation are presented below. Each of these is based on some combination of ideas from behavioral and transportation literature and from the discussions with transportation and public safety practitioners as part of this exploratory study.

The theoretical context for these approaches is a no-notice high impact event that affects some part of a densely developed central city, under the assumption of the best case scenario (see 5.1). The three approaches share a common objective: to ensure the safety and mobility of pedestrians while minimizing the likelihood that they may contribute to evacuation traffic congestion. All three approaches assume that many evacuees decide to walk some or all the way to their preferred destination. This might be due to a lack of access to a private vehicle or to their decision about that mode of transportation not being the most suitable for evacuating quickly.

Table 2. Conceptual Approaches for Managing Pedestrian Evacuation in Metropolitan Areas, from the Perspective of Emergency Management

Approach	Strategic Objectives
1. Designate and manage separate evacuation corridors for outbound vehicles and for pedestrians.	• Minimize the need for complex logistical activities on the part of the transportation managers. • Minimize the number of points where pedestrians and vehicles are in close proximity.
2. Provide dedicated evacuation transit hubs at the outer perimeter of the evacuation zone.	• Minimize the distance that evacuees are on foot and exposed to certain hazards. • Provide a transit option for evacuees who began evacuation on foot due to lack of other options. • Avoid putting disruptive activities like bus loading in and around the command and operations area. • Increase the likelihood of having an appropriate space for gathering evacuees and loading buses. • Avoid the need for extremely complex logistical activities by transit services.
3. Provide "bus bridges" from where large numbers of people are emerging from the buildings to designated points at the edge of the area being evacuated.	• Reduce the magnitude of the evacuation stream of evacuees on foot in the area with the greatest potential for impeding vehicles. • Take the buses into the evacuation zone to provide greater visibility of the option to be evacuated by bus. • Give car-less evacuees with limiting conditions an option besides walking. • Provide a safe environment for evacuees when time or weather conditions are inimical for walking. • By using a short route loop, reduce the time it takes each bus to return to the staging area for another load.

5.3.1 Separation of Vehicle and Pedestrian Streams

In practice, vehicles and pedestrian traffic are normally separated, with vehicles on the street and pedestrians on the sidewalk. Keeping to the sidewalk is customary and normative for pedestrians, reinforced by social pressure and law enforcement. It doesn't work perfectly, but well enough to serve the purposes of both drivers and pedestrians most of the time. If the assumption is that most pedestrians will collectively maintain this familiar behavior when

evacuating from an urban area, unless some unusual situation exists, some predictions are offered about what authorities might expect.

For purposes of a rapid evacuation of a portion of a city, the large surge of both vehicles and pedestrians may make the customary separation more difficult to maintain. Once the evacuation pattern is established by law enforcement with transportation agency assistance, most vehicles and pedestrians will be going the same direction. The vehicles are likely to keep to the street, but pedestrians on sidewalks where capacity is exceeded are less likely to adhere to the norm for staying on the sidewalk. Gridlocked or slow moving traffic enables pedestrians to brave the street, which may be a prelude to many pedestrians taking to the street in order to go faster than the sidewalk crowd, thereby inhibiting the potentially faster progress of the vehicles.

In a large city, with many streets going in all directions, options are available for the emergency evacuation plan to call for physically separating the bulk of pedestrian evacuees from the vehicle stream. This can be done by establishing different, but basically parallel routes out of the dangerous zone. By ensuring that pedestrians have their own corridor, individuals or groups can evacuate at a pace that is comfortable for them and avoid interfering with the progress of vehicles or of each other. This approach reduces substantially the potential for pedestrians to be injured by vehicles or interfere with the progress of drivers. It also reduces the potential for personal conflict between drivers and pedestrians.

Several factors could adversely affect the successful implementation of this approach. It may be easier to hold vehicles to specific travel routes than pedestrians. Rather than the separate route designated for pedestrians, some of the pedestrian evacuees may attempt to use the sidewalks along the evacuation route for vehicles because of its greater familiarity, for example. However, as long as the pedestrians stay on the sidewalk, separation of streams is maintained although the flexibility for the pedestrians walking at different speeds or as a group is reduced. Furthermore, if vehicle traffic is moving at speeds of more than a few miles per hour, pedestrians are deterred from stepping into the traffic lane.

From the discussions and photographs of the evacuations in Washington, D.C., and New York City, there are clear examples of vehicles and pedestrians mingling in the same roadway space. Because it is unusual, it made news. However, not enough specific information was found to know if this occurred in very many places. Competition for the roadway was particularly the case when the evacuation route included a bridge, tunnel, or other type of chokepoint for traffic. Whether pedestrian and vehicle streams use separate corridors or share the same one, they will compete for use of a bridge that is part of the major, or only, route away from an area unless there are enough alternative routes to also designate at least one for vehicles and one for pedestrians. The one designated for outbound pedestrians may need to have lanes designated for inbound emergency response vehicles.

In Manhattan, for example, street options for separate vehicle and pedestrian streams are available in all directions and there are several bridges and tunnels for traffic leaving the Island. Working from the experience with the 9/11 evacuation, the NYC emergency plans now include the contingency of different bridges and tunnels designated for pedestrian, personal vehicle, and emergency vehicle use when the objective is to clear an area of the city quickly, without regard for the direction people would prefer to go. This means the decisions have been made in advance

and can be immediately implemented as soon as law enforcement personnel can get in position. Some alteration of the designations may need to be made, for example, due to contingencies related to the impact zone, but the decision procedure will be quicker than if the law enforcement and transportation agencies have discussed the details of implementing such a plan in advance. For cities without a basic grid pattern in and around the downtown the designation of separate but parallel corridors may be more difficult. Most large cities will have some barrier such as a river or Interstate highway that result in chokepoints for traffic needing to be bridged across these features.

The greatest challenge for establishing the separate corridors is probably at the point where people begin emerging in large numbers from the downtown buildings in the evacuation zone. The evacuation of tens of thousands of people from large buildings at approximately the same time overwhelms the capacity of the sidewalks. Until evacuees have meaningful instructions on what to do next, large numbers are likely to mill around trying to find out what is expected of them or what others are going to do, even if it impedes vehicles in the area. The sooner it is made evident that there is an "appropriate" action to take in order to clear the area, the sooner some of the pedestrians will begin to move. Basic social forces will serve to prompt the bulk of the pedestrian mass to do the same thing. This is probably the best time for establishing separation of pedestrians and vehicles onto different streets. A major objective is to eliminate as much as possible cross traffic of vehicles or pedestrians while the bulk of the evacuees move away from the dangerous zone.

The establishment and use of totally separate corridors for vehicle and pedestrian streams may be the ideal of metropolitan emergency evacuation planners and public safety authorities. However, there are other adequate if not perfect solutions for keeping vehicles and people separate enough to maintain safety and mobility for both evacuation modes. For example, outbound lanes of a roadway can be designated for outbound vehicles, and the inbound lanes can be shared by incoming emergency vehicles with pedestrians using the sidewalk along that lane, facing the approaching emergency vehicles. Keeping to the right side of a center line is normative behavior for drivers and even more so if there is law enforcement presence. Behavioral research indicates that in the early stages of emergency situations most people tend to see themselves as part of the collective emergency activity, and a high degree of cooperative activity to reinforce the official enforcement can be expected. News media photographs from New York City on 9/11 show a major roadway with pedestrians clustered in a column along the left side and a few scattered emergency vehicles moving in the opposite direction. Photographs also show that at least one bridge also was shared in this manner, with pedestrians having all outbound lanes and only emergency vehicles using the inbound lanes.

5.3.2 Evacuation Transit Hubs to which Pedestrians Can Walk

For this approach, buses would be staged to take large numbers of people to designated areas. Dedicated buses are made available, but the staging area for boarding will be outside the zone being evacuated. The evacuees must walk to the buses, the distance being dependent on the size of an evacuation zone. The evacuees are then transported further out from the evacuated zone to one of several pre-designated locations, such as shopping malls, that have the services evacuees will need for personal comfort and making family contacts. From these locations individuals can arrange transportation to their preferred destination. The emphasis of this approach is to get as

many people away from the dangerous area as quickly as possible by having them leave from wherever they are at the time of impact using the route most directly outbound from that part of the city

As part of this approach, there is the assumption that most people who work in the city will have driven into the city and will attempt to use their private vehicle for evacuation. Others who are car-less and able or who decide walking is going to be faster than driving, can walk the same outbound route as that designated for the outbound vehicles, although possibly on a different street that the outbound vehicles. Those on foot will have to go only as far as the staging area for the buses. Given the typically sprawling footprint for the residential areas of most U.S. cities, people who leave the downtown area on foot will need to arrange private transportation to get home or to some other preferred destination. The areas designed as the destinations for the bused evacuees should be selected to be easily accessible for the drivers of private vehicles coming to pick up an evacuee. From there the evacuee may have to drive back to a location at the other side of the central city, but this will be taking place in a part of the city where vehicles will be going all directions under normal traffic control.

The approach of using a dedicated bus service for ferrying pedestrians between two fixed locations is consistent with existing downtown evacuation plans that were described by representatives of two medium-sized cities, Cleveland, Ohio, and Charlotte-Mecklenburg, North Carolina, for this study. Each of these plans sets forth a basic concept for downtown evacuation by starting with a planning assumption that the impact and hazard area is basically centered in the downtown area, and evacuees can travel outward in one of several directions to get out of the hazard area.[35] A map is drawn up to designate quadrants and several streets selected in each quadrant as best for outbound evacuation routes for vehicles. The Charlotte map also indicates pedestrian routes, some of which are the same as the outbound vehicle routes and some are on different streets.

The selection of the streets that are actually used during an evacuation will depend on the nature and location of the extreme event that precipitates the emergency evacuation. Traffic control personnel will direct traffic to the routes that are determined to be most usable and most suitable for effective evacuation and will control the traffic on these routes to prevent cross traffic that would slow down the outward progress. Each plan was developed through a multi-agency planning process that also includes the downtown business associations. Businesses are expected to participate in the periodic education of the downtown workers about the downtown evacuation plan and potential routes. To the extent that evacuation by private vehicle is possible, the planners assume vehicles will be the evacuees' preferred mode. In an actual event the zone to be cleared is not likely to be exactly the same as that on the map, but the basic concept of driving or walking directly away from the dangerous area is still operable. It will be necessary for law enforcement officers or other traffic controllers to direct evacuees away from the impact zone to the pre-designated routes that are appropriate under the circumstances.

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[35] For the Cleveland downtown evacuation plan, see: <http://www.city.cleveland.oh.us/emergency/downtownemergencyevacuationplan/dowtownemerevacind.html> For Charlotte-Mecklenburg plan see: <http://www.charmeck.org/Departments/Police/Home.htm> , Center-City Emergency Evacuation Plan.

In short, the basic concept is that evacuees will either drive out or walk out of the area, using evacuation routes that are designed to minimize cross traffic. The plans are designed to accommodate both a typical vehicle evacuation and a mainly pedestrian evacuation. For pedestrians, each quadrant has a designated "transit hub area" located approximately one to two miles from the center of the downtown, where existing facilities in these areas can accommodate large numbers of people and a bus loading area. In an emergency evacuation, buses will be deployed immediately to these transit hubs. This approach is more efficient and removes potentially disruptive traffic from the site directly affected by the emergency situation. Pedestrian evacuees who walk to these transit hubs will be bused away from the downtown area to other designated evacuation facilities such as shopping malls, where evacuees will have access to such things as restrooms, telephones and food. At this point, it is up to them to find their way to their preferred destination, while avoiding the evacuated downtown area.

5.3.3 "Bus Bridges" to Move Pedestrians out of the Dangerous Zone

Compared to commuter rail, buses have a greater routing flexibility, including being routed around damaged or dangerous areas and to a larger selection of destinations. One frequent contingent use of buses is to provide "bus bridges" around portions of a commuter train route that is temporarily inoperable. Special purpose bus routes and service also are used for pre-planned special events (e.g., concerts, sports events) in order to reduce traffic congestion at the event facility. The bus service is provided between the event venue and a designated location beyond the more congested zone, as a "bus bridge" for people who don't want to drive in the post-event congestion.

This concept of taking the buses to where the people are and the experience with the logistics of doing this held by special events planners, provide a basis for designing an evacuation shuttle service. To make this a safe option for the evacuees not using private vehicles, the emergency response command will have to have confidence that it is safe to have large numbers of people gathered near the impact zone and that there is an area suitable for waiting and then boarding buses as they become available. If that is the case, this approach might be particularly important to consider under circumstances such as bad weather, nighttime, or as the option for people who know they cannot walk very far due to health conditions.

The main objective of this arrangement in an emergency evacuation would be to gather up evacuees as they evacuate buildings and move them quickly beyond the perimeter of the hazard zone or beyond the most congested area. This is best accomplished if an area suitable for use as a staging area for the buses and pedestrians can be quickly determined and loading queues established. As people evacuate buildings, they can be directed to the staging area. This helps to alleviate the situation where evacuees mill around outside their buildings, waiting for some instruction about what they should do next.

Pedestrians can be guided toward the staging area where buses continually arrive, load, and leave, taking the riders along streets designated for the buses to a specified area where it is safe for them to disembark. At this point, the evacuees would again become pedestrians, but would then be in an area where they can collect their thoughts and proceed at their own discretion with respect to direction and mode. People who prefer to keep walking can do so.

Major logistical challenges must be addressed to implement this concept for ferrying large numbers of evacuees even a short distance. The primary drawback is that without advance notice, it will take time to get buses and drivers in place. One solution might be to redirect buses from the scheduled routes in the area and make more efficient use of them for the evacuation than keeping them on their normal routes. Personnel to carry out information, assistance, and control activities also will have to be assigned to the loading area. Another potential drawback is that service capacity might be quickly overwhelmed and result in large numbers of pedestrians accumulating at the assembly areas.

Evacuees will assess the situation from their own personal perspective and are likely to sort themselves into those who prefer to keep walking and those who need or prefer to ride to a safer place. Given the logistical demands for implementing this approach quickly enough to serve emergency evacuation needs, it must be designed in concept as part of emergency preparedness activities. The concept of operations will have to be worked out in advance, and in coordination with other agencies that must be familiar with it and prepared to support it. The decision to implement it as part of the overall evacuation strategy can be made as soon as the incident command determines the area is safe enough for this activity.

5.4 Minimizing Mixed Pedestrian and Vehicle Congestion

There are at least three other theoretically logical approaches; minimize evacuation by private vehicle; minimize evacuation on foot; and, minimize evacuation.

5.4.1 Prohibit or Minimize Private Vehicle Evacuation

Many examples exist of traffic delays occurring when extraordinarily large numbers of people leave in private vehicles from the same general area at about the same time. The subject matter experts at the working group meeting for the study addressed the issue of how to identify and implement the most effective protective action for downtown populations during an emergency evacuation. If law enforcement and transportation authorities do not have sufficient advance notice of the need to deploy traffic control resources for a sudden emergency response, major traffic congestion is sure to ensue. In the early stages, at least, pedestrians are likely to make faster progress than vehicles. If evacuees are prohibited from using private vehicles for evacuation, the outbound pedestrians will have even more flexibility in the use of the roadway, with the exception of corridors for emergency response vehicles and other authorities. Under certain circumstance simply telling people to ‘run for their lives,’ so to speak, might result in the most lives saved. This extreme form of pedestrian evacuation, however, is not appropriate for several segments of special needs populations. Also, the ability to ensure the presence and coordination of enough law enforcement and other resources to enforce a prohibition of private vehicle use would present a major challenge.

5.4.2 Prohibit or Minimize Evacuation on Foot

The theoretically logical option opposite of minimizing vehicle evacuation is minimizing the number of pedestrians competing for the same roadway as vehicles. That is, the restriction could be on walking unless the destination was to a nearby transit option, so that all evacuation is carried out with vehicles. To some extent, this is the ad hoc situation for many evacuations

carried out in small and medium sized towns. In a large city, with many car-less people, this might be difficult to implement. However, examples of some of the processes for accommodating large numbers of people with private vehicles and mass transit have been demonstrated in New York City and Washington, D.C. For example, in 9/11 around the bridge and tunnel chokepoints for leaving Manhattan, police requested that motorists provide rides to evacuees approaching these points on foot. A similar use was made of the excess capacity in private vehicles during the New York City December 2005 transit strike, for both in-bound and outbound commuters. In Washington, D.C., normal commuting patterns include commuters who routinely request rides with strangers.

5.4.3 Prohibit or Minimize Evacuation

The third theoretically logical concept for eliminating the problems and delays associated with an evacuation is to order that people stay where they are until some dangerous period is over. This "shelter-in-place" approach as an option already is included in many emergency plans, especially around fixed-site hazardous facilities. A circumstance under which emergency managers may want to instruct people to shelter in place is the confirmed or probable presence of a toxic or radiological airborne plume. Skilled responders will have a fairly good idea of where the plume is, what direction it is moving, and how long it will take for it to pass over a specific area; the layperson without the expertise and equipment to determine the path of the plume is better off to stay put indoors in a recommended location. For many types of releases, sheltering in place in substantial buildings can at least reduce exposure while a plume passes. If the plume path is contaminated, the authorities will have to determine when and how people can leave the buildings that were in the path. People also may be advised to forgo evacuation and stay sheltered if there is a credible threat of something dangerous about to happen, but no credible information on the location it will affect. The little research found on how well people comply with advisories or orders to shelter in place indicates that many say they will do so, especially if they have received education about sheltering as a protective action. The actual level of compliance will depend on several factors. One factor is whether people perceive the instructions to be clear with respect to what they are to do and for how long. Another will be what other people in the same vicinity are doing, sheltering or evacuating.

6 CONCLUSIONS AND RESEARCH RECOMMENDATIONS

The literature review and interviews for this project indicated that until emergency evacuation plans for towns and cities have focused mainly on the movement of people in private vehicles. Little mention was found of pedestrians (other than as building evacuees) in the past research on emergency evacuations. The evidence indicated that little attention has been given to instructions and routing for people evacuating a section of an urban area on foot. With the public's reactions to the 9/11 attacks came news service photographs and accounts of people leaving office buildings in New York City and Washington, D.C., and not necessarily using a private vehicle or mass transit to leave the city. Many are thought to have walked long distances if it was necessary to arrive at their preferred destination, usually their residence. Since 9/11, some cities have begun to consider pedestrians in their evacuation plans, such as those developed for Cleveland, Ohio, and Charlotte-Mecklenburg, North Carolina (see Section 5.3.2 above).

6.1 Practitioners' Concerns

During this research, discussions with 23 persons representing an array of disciplines from transportation and public safety practitioners to social and behavioral science researchers revealed a range of issues to be addressed if emergency evacuations from big cities are expected to involve large numbers of both private vehicles and pedestrians. Transportation officials in particular voiced concerns about whether pedestrians can be kept safe, since they cannot be managed and channeled as easily as can vehicles. This was at least partially based on having witnessed pedestrians walking in the roadway among vehicles in some locations in New York City and Washington D.C. Public safety and behavioral science experts generally agreed that it can be difficult to deter pedestrians from taking direct routes to destinations, or to deny them access to a familiar route. The social scientist experts in disaster behavior are confident that pedestrian evacuees will behave in an orderly adaptive manner, including looking out for and helping each other and staying out of the way of emergency responders.

Most emergency response experts acknowledge that in any emergency or sudden threat situation, people need and want information. For that information to result in appropriate protective behavior, what people are told at any given time must be relevant to their decision-making about appropriate action, even if it is not a complete picture of the emergency or a threat. Research findings on emergency evacuation behavior and management of special events suggest that people leaving buildings are likely to move away from where they emerge from buildings if they have an indication of which direction or directions are appropriate and safe. Planning for pedestrians in emergency evacuations must address how to determine the appropriate direction under the circumstances and how this guidance is provided to those who are evacuating. A major issue for consideration is that of what strategy for evacuating a major downtown area will result in the least harm to the evacuees. Dilemmas will emerge. For example, when gridlocked traffic conditions curtail mobility of drivers; walking may be faster in general but not possible for certain people; being in the open air prolongs exposure for those walking along distance. The use of special evacuation transit may promise faster and safer evacuation, but the capacity of the buses not adequate for a sudden surge of evacuees, leaving many evacuees waiting for carriers to drop off evacuees and return to the downtown area for more.

6.2 Research Needs

Up to this time, evacuations from large, highly concentrated cities similar to New York City are too few in number to provide much information to go on for knowing what to expect. Systematic study of large-scale pedestrian evacuation in U.S. cities still is needed to better understand how pedestrian evacuees react to various types of settings, situations, and instructions. Some of the participants in the study remarked that on 9/11 and during the extensive August 2003 blackout in the northeastern states, the time-concentrated exodus by the urban workers who lived elsewhere was essentially an extremely heavy end-of-the-day commute. That is, people going home don't just move as far as is necessary to be safe, but instead continue on to their residence. They know their destination, which is likely to be at some distance from the perimeter of the area defined as dangerous; they work out a way to get there under the circumstances. This pattern of workers evacuating and heading home, even on foot, raised questions about how far and by what routes and transportation modes urban evacuees will travel, and what services they will need or want along the way. Even less well understood is the likely behavior of people who live and work in the downtown area, and who may be car-less by choice. They may make the decision to evacuate, leaving their home and possessions temporarily, but may not have to travel very far to come to a part of the city that is not being evacuated.

Transportation managers and researchers need to be prepared to conduct studies following the next case of a major metropolitan evacuation from a no-notice event. FHWA sponsored relatively detailed case studies of the 2001 and 2003 evacuations from New York City and Washington, D.C., but the objective of the case studies was to determine the disruptions to transportation activities and adjustments made by the transportation agencies. Consequently, the large number of people evacuating on foot was more a finding than a focus of the inquiries.

Disaster researchers from the behavioral disciplines tend to be skeptical of emergency plans that specify what the evacuation planners see as the best thing for people to do. Social scientist disaster researchers advocate for emergency evacuation planning that takes into account how people are likely to respond based on what is known about social behavior in threatening situations and in response to warnings. With the exception of the 9/11 events, there have been no large-scale evacuations in major U.S. metropolitan areas precipitated by a sudden "no-notice" event or threat. Even in reports of the response during the 9/11 events, there is little information about whether pedestrian evacuees were given any instruction by authorities as to evacuation routes and if so, how the evacuees responded to instructions or advice.

Past research from other types of disaster cases indicates that in the immediate post-impact stage, people tend to be reasonable and adaptive. They also will be cooperative with authorities when they think they have received adequate information about the danger and appropriate protective actions. Case studies of large-scale urban evacuation are needed to what the specific decisions and actions are in these urban contexts. The most commonly observed response and evacuation behavior has been in the context of the traditionally structured environment of smaller cities and towns. Persons living in high density urban environments and more used to the congestion and transportation alternatives can be expected to collectively adjust their behavior to that context.[36]

[36] Perry, 1982.

The unanticipated emergence of pedestrian evacuees in New York City and Washington, D.C., in the face of the 9/11 situation provides some evidence that this may be one of the adaptations to that context. Indeed, urban dwellers may have learned from their observations of these events. Not only was evacuating on foot "publicized" through media accounts as an option during urban evacuation events, but the delays described because of the initially gridlocked traffic may result in other urban dwellers considering options other than driving, should the need to evacuate from a downtown area occur. Circumstances that differ in many high density downtown areas, compared to smaller cities, include better walking facilities, more mass transit options, and a greater likelihood that a large proportion of the evacuees are headed home, instead of to some unfamiliar location to wait out the evacuation situation

6. 3 Research Opportunities and Issues

At the moment of this report, there are two major opportunities for gathering more systematic detail about urban evacuations involving pedestrian evacuees: the last case and the next one. The most recent cases would be that of people leaving Lower Manhattan after it became evident that the planes hitting the World Trade Center towers were no accident, and the government and other office workers voluntarily leaving downtown Washington, D.C., as news of the attacks emerged. Various types of research were found in relation to New York City, but none was identified that provided an overview of the decision points of the pedestrian evacuees or the interactions between pedestrians and the agency officials with roles related to facilitating the temporary evacuations. Now that issues have been raised about pedestrian evacuation, preparations should be made for research on the next case as well. General areas of recommended research about the management and accommodation of pedestrians from these two past cases and in the next no-notice urban evacuation follow.

6.3.1 Research on the Past Evacuations

In order to better understand the nature of pedestrian evacuations in U.S. cities in response to a no-notice event it will be necessary to employ various research techniques to glean further information from the 9/11 evacuations of Lower Manhattan in New York City and Washington, D.C. While these two evacuation examples are several years old and officials directly involved likely to have dispersed to some extent, the scarcity of such events as opportunities to pursue the topic of pedestrian evacuation lend value to such research. This research was completed before the September 2005 hurricane season.

Nonetheless, the evacuations in relation to warnings about the approaching Hurricanes Katrina and Rita in 2005 do not seem to provide examples needed for understanding the issues raised for research on no-notice evacuations. For example, a telephone survey conducted by Harvard Medical School[37] found that, as typical of hurricane evacuations, about 75% of the respondents from the New Orleans Metropolitan Area had evacuated at some point before the hurricane made landfall. Of the 25% of the sample who said they had not evacuated, about 40% of them said they did not evacuate because they felt the storm would not be that bad, while another 40% said they did not evacuate because of a lack of money. The subsequent and unanticipated flooding

[37] Harvard Medical School, 2006.

from the levee failures clearly called into view issues relating to a need for being prepared to provide specialized transportation assistance in urban evacuations. Once the unanticipated flooding started, official activities are better characterized as rescue for people who had remained in their neighborhoods and institutions rather than as an evacuation situation. As an example of research approaches and questions for examining the 9/11 evacuations, the approaches to consider include systematic surveys of individual behavior, interviews with agency officials, in particular law enforcement and transportation agencies, and compilation of private and public video recordings from the morning of 9/11, such as the following:

- Survey research with samples of individuals who worked in office buildings in Lower Manhattan or in Washington, D.C., on 9/11 could provide information with which to compare the actions of people who worked and lived in the area downtown area to those who worked downtown but lived elsewhere. This information could be compared to findings from earlier research on evacuations from cities and towns of lesser population density, with respect to information seeking and use in relation to evacuation decision making.

- Survey research to collect information from individuals could compare the experience and the bases for decisions about evacuation modes across people who left the city in a private vehicle, those who left behind a private vehicle in preference for another mode of travel, and car-less residents or workers who walked or used mass transit or both, to leave the city.

- Interviews by social scientists with key staff from across several relevant agencies could be used to triangulate the observations of officials (e.g., law enforcement, traffic control, and transit personnel) who were located in different parts of the city and operations centers when the evacuation began and as it progressed. This could help to pinpoint if, how and where pedestrians, private vehicle traffic, and emergency vehicle traffic were intermixed and how situations of traffic and pedestrian congestion were resolved. Findings from such research would help identify the factors related to such congestion, the ways in which safety and mobility were affected, what might be effective approaches for mitigating such congestion, and what specific messages for evacuees were provided through which means.

- Compilation of photographic records (both still and video captured by private, mass media, and even surveillance cameras), identified with respect to specific location, could provide important details about the routes and behaviors of the pedestrian evacuees and of interactions between pedestrians and officials as the basis for providing scenarios for consideration by the city's evacuation planners. The photographic record of New York City from the morning of 9/11 appears to be far richer than that for Washington, D.C., probably due to the dramatic events in the heart of the Manhattan business district. The exodus of people from Washington D.C., (as opposed to those leaving the Pentagon) was not in response to actual damage in downtown Washington and thus was not accompanied by large numbers of inbound emergency response vehicles for which traffic lanes controlled nor the shut down of MetroRail for transportation out of the downtown area.

6.3.2 Research on the Next Evacuation

If transportation and emergency management agencies view as high priority the possession of better information on which to base planning assumptions about evacuations with large numbers of people on foot as well as in vehicles, it is important that the decision to collect this information be made in advance of the next event. Timely post-disaster research calls for consideration of how to make resources immediately available for data collection. Examples of this type of contingent research funding in past decades can be found with the National Science Foundation, the National Research Council, and the National Institute of Mental Health. Needless to say, the more resources that can be made available, the more extensively and systematically the question of pedestrian evacuation, as a phenomenon or an official strategy, can be studied using the various research approaches and data sources.

Agencies responsible for urban emergency evacuations need to consider what types of information are most important in their view to be obtained from the next evacuation of a highly concentrated metropolitan area in response to a no-notice event or credible threat. Information collected within weeks or months of the event is less likely to have suffered distortions that inevitably creep into accounts provided long after the event. Research techniques and questions appropriate for this task are the same as those suggested for research on the 9/11 evacuations, including the following:

- Scientifically designed surveys of individuals who worked in the large office buildings in the area from which people evacuated, to obtain information about what mode they used and why, the information they used to make the decision, how they chose their destination and their route, and whether they would do the same thing in the future.

- Scientifically designed surveys of individuals who had a residence in the area from which people evacuated, to obtain information about their evacuation decision and timing, the information with which they made this decision, their transportation options and choice of mode, and their experience with determining and reaching a preferred destination.

- Semi-structured interviews with key officials and field operations staff from transportation (traffic and transit), law enforcement, and emergency management agencies, to obtain information about patterns of evacuation that emerged including specific attention to pedestrians, any variation apparently related to a certain location or characteristic of the city, effectiveness of planned or ad hoc measures taken by the agency in relation to the evacuation pattern, and advice they would give to evacuation planners in other large cities.

- An appropriate operational or research agency could make an immediate request to agencies and organizations that might have some photographic record of such aspects as: the flow of evacuees on foot, for example, as they left their buildings; approached transit loading areas; approached chokepoints such as a single roadway, bridge, or tunnel for egress from the area being evacuated; and where they began to disperse as a mass of pedestrians. Such otherwise quickly disappearing “data sets” might exist with the mass media, private citizens’ video recordings, traffic and security surveillance cameras at intersections and on buildings, ATMs, fortuitously-timed satellite photographs, and so forth. These records could be compiled and used to prepare a large scale and graphic

overview of a phenomenon that is difficult to make sense of when viewed from only one or two locations. This information could be used by evacuation planners to consider appropriate measures for facilitating and managing both traffic and pedestrians, or for comparing the time and distance of drivers and pedestrians in the first hour or so.

6.4 Summary and Conclusions

In summary, the main intent of this study was to try to identify practices or ideas that transportation managers and public safety agencies were planning or maybe had actually used, to ensure that people evacuating on foot and people evacuating in vehicles did not hamper each others' mobility in relation to a safe and preferred destination.

Practitioners expressed concern that they had not given adequate thought to planning for large numbers of people evacuating on foot, now that there was some indication this may occur in large cities. The discussions with the practitioners also indicated they believe the usual techniques for traffic congestion management can be used. However, they assert that emergency planners need to focus much more attention during preparedness planning on evacuation scenarios that provide planning assumptions for pedestrian evacuation.[38] The public safety practitioners emphasize that the basis of effective emergency response of any type is the development of close and continuous working relationships across agencies. The transportation practitioners add to this that the transportation agencies have traditionally responded based on decisions and directives of others. Among other things, the development of intelligent transportation systems (ITS) now put them in the position of being able to make major contributions of information during disaster response and the means to provide information to the public, and especially travelers. Transportation agencies also are increasingly using public education campaigns to familiarize drivers and riders with options and information sources. These ITS assets and education campaigns can be capitalized on for the development of information sharing and dissemination for managing both traffic and pedestrians during major disruptive events. Transportation officials need to have greater participation during city evacuation planning and to provide a more proactive presence during emergencies.

In conclusion, based on the information collected for this report, it seems reasonable to say that the factors associated with the emergence of a large scale pedestrian evacuation from a section of a large U.S. city are not as yet very well understood. Since 9/11 several U.S. cities have begun to incorporate the possibility of people choosing or needing to leave a downtown area on foot in preference to driving. Evacuation planners view as credible the image of the almost impenetrable traffic gridlock that can occur if downtown populations suddenly begin to leave the city because of a no-notice event or threat.

At the same time, discussions with transportation and response practitioners and disaster researchers raised the issue of considering pedestrian evacuation as the quickest option for getting large numbers of people away from a dangerous area in a concentrated urban area. Thus, further research is needed to help clarify the planning assumptions for managing a metropolitan-

[38] For example, see the ESF#1 Coordination Worksheet of the Washington Metropolitan Area Regional Emergency Coordination Plan, p. 107.

based pedestrian evacuation. Pedestrian evacuation can be seen as a phenomenon that responders should consider in order to be prepared for the potential that large numbers of people may decide to evacuate on foot, along with vehicle traffic. On the other hand, evacuation planners may want to consider under what circumstances the deliberate implementation of a pedestrian evacuation might be a preferred and feasible strategy for most quickly getting the largest number of people out of harm's way.

REFERENCES

Abkowitz, M., & Meyer, E. (1996). Technological advancements in hazardous materials evacuation planning. *Transportation Research Record*, v. 1522: 116-121.

Alam, S. B., & Goulias, K. G. (1999). Dynamic emergency evacuation management system using geographical information system and spatiotemporal models of behavior. Transportation Research Record, v. 1660: 92-99.

Bayles, F., & Hampton, R. (2003). Disasters at clubs repeat tragic history. *USA Today*, 01A, Feb. 24.

Campos, V., da Silva, P., & Netto, P. (2000). Evacuation transportation planning: A method to identify optimal independent routes. *Fifth International Conference on Urban Transport and the Environment for the 21st Century*, 555-564.

Carter, M.R., Howard, M.P., Owens, Nicholas, et al. (2002; July, Draft). Effects of Catastrophic Events on Transportation System Management and Operations, Howard Street Tunnel Fire, Baltimore City, Maryland—July 18, 2001. Prepared by Science Applications International Corporation for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

Carter, M.R., Howard, M.P., Owens, Nicholas, et al. (2002; March, Draft). Effects of Catastrophic Events on Transportation System Management and Operations, The Pentagon and the National Capitol Region—September 11, 2001. Prepared by Science Applications International Corporation for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

City of Oklahoma. (1996). Alfred P. Murrah Federal Building Bombing, April, 19, 1995, Final Report. Oklahoma City: Fire Protection Publications.

Crowd Dynamics. Primary url is: http://www.crowddynamics.com.

Page for descriptions of crowd stampede episodes is:
http://www.crowddynamics.com/Main/Crowddisasters.html
(Accessed November 8, 2004.)

DeBlasio, A.J., Regan, T.J., Zirker, M.E., et al. (2002, April, Draft). *Effects of Catastrophic Events on Transportation System Management and Operations, New York City—September 11.* Prepared by the Volpe National Transportation Systems Center for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

DeBlasio, A.J., Zamora, A., Mottley, F., et al. (2002, April, Draft). *Effects of Catastrophic Events on Transportation System Management and Operations, Northridge Earthquake—January 17, 1994.* Prepared by the Volpe National Transportation Systems Center for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

DeBlasio, A.J., Regan, T.J., A., Zirker, M.E. Fichter, K.S., & Lovejoy, K., (2004) Effects of Catastrophic Events on Transportation System Management and Operations, August 2003 Northeast Blackout: Great Lakes Region. DOT-VNTSC-FHWA-04-02. Prepared by Volpe National Transportation Systems Center for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

DeBlasio, A.J., Regan, T.J., A., Zirker, M.E. Fichter, K.S., & Lovejoy, K., (2004) Effects of Catastrophic Events on Transportation System Management and Operations, August 2003 Northeast Blackout: New York Region. DOT-VNTSC-FHWA-04-04. Prepared by Volpe National Transportation Systems Center for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

DeBlasio, A.J., Regan, T.J., A., Zirker, M.E. Fichter, K.S., & Lovejoy, K., (2004). *Effects of Catastrophic Events on Transportation System Management and Operations. Comparative Analysis.* DOT-VNTSC-FHWA-04-03. Prepared by Volpe National Transportation Systems Center for the U.S. Department of Transportation. Washington, D.C.: Federal Highway Administration, ITS Joint Program Office.

Dixon, J. (2001). Building agency blasted Detroit audit cites mismanagement, inconsistency. *Detroit Free Press*, 1A, Jan. 15.

Drabek, T. E. (1969). Social processes in disaster: Family evacuation. *Social Problems, 16*(3): 336-349.

Drabek, T.E. (1986). Human System Responses to Disasters: An Inventory of Sociological Findings. New York: Springer-Verlag.

Drabek, T.E., (1995). Disaster Responses within the Tourist Industry. *International J. of Mass Emergencies and Disasters*, 13(1): 7-23.

Drabek, T.E. (1996). *Disaster Evacuation Behavior: Tourists and Other Transients*. Program on Environment and Behavior, Monograph No. 58. Boulder, CO: University of Colorado Institute of Behavioral Science.

Eisler, P., Bayles, F., & Vergano, D. (2001). U.S. cities brace for the next acts of terrorism. *USA Today*, 01A, Sept. 24.

Federal Highway Administration (FHWA). Emergency Transportation Operations (ETO). http://www.ops.fhwa.dot.gov/opssecurity/case_studies/index.htm (Accessed Oct. 6, 2006)

Feinberg, William E.; Johnson, Norris R., (2001). The Ties that Bind: A Macro-Level Approach to Panic. *International J. of Mass Emergencies and Disasters*; 19(3): 269-95.

Fischer, Henry W. I., (1998). *Response to Disaster: Fact Versus Fiction & Its Perpetuation* (2nd Edition); Lanham, MD: University Press of America, Inc.

Fitzpatrick, C., & Mileti, D.S. (1991). Motivating public evacuation. *International Journal of Mass Emergencies and Disasters*, 9(2): 137-152.

Fruin, J.J. (1987). *Pedestrian Planning and Design*. Mobile, AL:Elevator World, Inc.

Harvard Medical School. (2006). Overview of Baseline Survey Results. Hurricane Katrina Community Advisory Group, August 20. 2006. www.hurricanekatrina.med.harvard.edu (Accessed November 3, 2006).

Helbing, D., Farkas, I.J., Molnar, P., & Vicsek, T. (2001). Simulation of pedestrian crowds in normal and evacuation situations. Pp. 21-58 in Schreckenberg, M., and Sharma, S.D. (eds), *Pedestrian and Evacuation Dynamics*, Berlin:Springer.

Keating, John P., (1982). The Myth of Panic. *Fire Journal*. May: 57-62.

Lang, K., & Lang, G. E. (1961). *Collective Dynamics*, Oxford, England: Crowell.

Li, Q, & Wang, Y. (2004). GIS-based emergency evacuation computer simulation system. *Proceedings of the ITS America 14th Annual Meeting*, 14p.

Lindell, M.K., & Perry, R.W. (eds.), Evacuation Research: Theory and Applications. Special Issue, *International Journal of Mass Emergencies and Disasters*, 9(2): August 1991.

Lindell, M.K., & Perry, R.W. (1992). *Behavioral Foundations of Community Emergency Planning*. Washington: Hemisphere.

May,Peter J., and Williams, Walter. (1986). *Disaster Policy Implementation*. NY: Plenum.

Mitchell, Jerry T.; Thomas, Deborah S. K.; and Hill, Arleen A., et al. (2000). Catastrophe in Reel Life versus Real Life: Perpetuating Disaster Myth through Hollywood Films. *International J. of Mass Emergencies and Disasters*. 18(3): 383-402.

New York City Emergency Response Task Force. (2003). *Enhancing New York City's Emergency Preparedness: A Report to Mayor Michael R. Bloomberg*. New York City: Mayor's Office, Oct. 28.

NUREG/CR-6864v2. Identification and Analysis of Factors Affecting Emergency Evacuations. Appendices. http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6864/ (Accessed Oct. 6, 2006.)

Pacheco-Costello, D., Maguire, S. & Chang, E. C. (2002). Understanding human behavior for effective evacuation planning (CD-ROM). *Proceedings of the 9th World Congress on Intelligent Transportation Systems*, 18p.

Pal, A., Graettinger, A. J., & Triche, M. H. (2003). Emergency evacuation modeling based on geographical information system data (CD-ROM). *82nd Annual Meeting of the Transportation Research Board.*.

Pangi, Robyn. (2002). *Consequence Management in the 1995 Sarin Attacks on the Japanese Subway System*. BCSIA Discussion Paper 2002-4, Executive Session on Domestic Preparedness

Discussion Paper ESDP-2002-01. Boston: Harvard University, John F. Kennedy School of Government.

Perry, Ronald W., (1982). *The Social Psychology of Civil Defense*. Lexington, MA:D.C. Heath.

Perry, Ronald W. and Lindell, Michael K., (2003). Understanding Citizen Response to Disasters with Implications for Terrorism. *J. of Contingencies and Crisis Management*. 11(2): 49-61.
Petruccelli, U. (2003). Urban evacuation in seismic emergency conditions. *ITE Journal, 73*(8): 34-38.

Proulx, G. (1991). Passengers' behaviour during an underground evacuation. *Proceedings of the International Conference of the Environmental Design Research Association*. EDRA-22: 118-125.

Proulx, G. (1993). A stress model for people facing a fire. *Journal of Experimental Psychology, 13*(5): 918-934.

Proulx, G., & Sime, D. J. (1991). To prevent panic in an underground emergency: Why not tell people the truth? In C. Cox & B. Langford, Eds., *Fire Safety Science – Proceedings of the Third International Symposium*. London: Elsevier Applied Science, 843-852.

Quarantelli, E.L., (1954). The nature and conditions of panic. *American Journal of Sociology,* 60: 267-275.

Quarantelli, E. L., (1981). *Panic Behavior in Fire Situations: Findings and a Model from the English Language Literature*; Newark, DE: University of Delaware, Disaster Research Center, Publication No. 144.

Riad, J. K., Norris, F. H., & Ruback, R. B. (1999). Predicting evacuation in two major disasters: Risk perception, social influence, and access to resources. *Journal of Applied Social Psychology, 29*(5): 918-934.

Rocco, A., Daniels, F., Acampora, P., Ackerman, G., Schneiderman, J., & Pace, F., (2001). Other voices: Could we evacuate in an attack?. *Newsday*, B07, Dec. 1.

Saavedra, C. (2001). How can we be best prepared?. *Miami Herald*, 27A, Sept. 14.

Scanlon, Joe, (1991). *Lessons Learned or Lessons Forgotten: The Canadian Disaster Experience*; Toronto: Institute for Catastrophic Loss Reduction, The University of Western Ontario.

Saloma, C., Perez, G. J., Tapang, G., Lim, M., & Palmes-Saloma, C. (2003). Self-organized queuing and scale-free behavior in real escape panic. *Proceedings of the National Academy of Sciences of the United States of America, 100*(21): 11947-11952.

Schreckenberg, M., & Sharma, S. D. (eds.), (2002). *Pedestrian and Evacuation Dynamics,* Berlin:Springer.

Sorensen, J. H. (1991). When shall we leave? Factors affecting the timing of evacuation departures. *International Journal of Mass Emergencies and Disasters*. 9(2): 153-165.

Sugiman, T., & Misumi, J. (1988). Development of a new evacuation method for emergencies: Control of collective behavior by emergent small groups. *Journal of Applied Psychology, 73*(1), 3-10.

Tierney, Kathleen J.; Lindell, Michael K.; and Perry, Ronald W. (eds.), (2001). *Facing the Unexpected: Disaster Preparedness and Response in the United States*; Washington DC: Joseph Henry Press.

Titan Systems Corporation. (n.d.). *Arlington County After-Action Report on the Response to the September 11 Terrorist Attack on the Pentagon*. Prepared for Arlington County under Contract GS10F0884K to the Office for Domestic Preparedness. Washington D.C.: U.S. Department of Justice.

United States Fire Administration. (n.d.) *The World Trade Center Bombing: Report and Analysis*. Report 076, Major Fires Investigation Project. Washington DC: Federal Emergency Management Agency, United States Fire Administration.

Van Bronkhorst, E. (1999). 2,100 rail passengers, no phones or ventilation? – Rapid-transit officials look at old tunnel's safety. *Seattle Times*, B2, August 29.

Walters, Lynne M.; Wilkins, Lee; Walters, Tim, (eds), (1988). *Bad Tidings: Communication and Catastrophe*; Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Washington Metropolitan Area Regional Emergency Coordination Plan (RECP), Revised Regional Emergency Event Transportation Coordination (REETC) Annex. March, 2004. http://www.mwcog.org/security/security/download/REETC%20Annex_2004003-04.pdf (Accessed Nov. 2006).

Willis, A., Kukla, R., Kerridge, J., & Hine, J., (2001). Laying the foundations: The use of video footage to explore pedestrian dynamics in PEDFLOW. Pp. 181-186 in Schreckenberg, M., & Sharma, S.D., (eds), *Pedestrian and Evacuation Dynamics*. Berlin: Springer.

Wolshon, B. (2004). A way out: The emergence of homeland security stresses the importance of evacuation management. *Transportation Management & Engineering, 9*(2), 16-21.

Zelinsky, W., & Kosinski, L.A. (1991). The Emergency Evacuation of Cities: A Cross-National Historical and Geographical Study. Savage, MD: Rowman & Littlefield.

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