NCHRP

REPORT 525

Surface Transportation Security

Volume 10

A Guide to Transportation's Role in Public Health Disasters

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OF THE NATIONAL ACADEMIES

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Volume 10

A Guide to Transportation's Role in Public Health Disasters

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Subject Areas
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Research Sponsored by the American Association of State Highway and Transportation Officials
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WASHINGTON, D.C.
2006
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 525: Volume 10

Price $39.00

Project 12-59(19)

ISSN 0077-5614

ISBN 0-309-09852-1

Library of Congress Control Number 2006902581

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Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

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AUTHOR ACKNOWLEDGMENTS

This report is the result of contributions from a number of individuals. The NCHRP Project 20-59(19) panel served as the primary advisor for this report. This report reflects the best judgment and experience of Science Applications International Corporation (SAIC) staff, who researched and developed this report from publicly available literature in addition to some personal interviews. The SAIC program manager was David Friedman. Primary authors of the CBR threat sections were Delma Bratvold, Steve Mirsky, Geoff Kaiser, and Paul Schaudies. The primary authors of the transportation overview section were Eric Bolz, Delma Bratvold, Ray Castor, and Fred Latham.

FOREWORD

By S. A. Parker
Staff Officer
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This tenth volume of *NCHRP Report 525: Surface Transportation Security* will assist transportation managers in the development of transportation response options to an extreme event involving chemical, biological, or radiological agents. The project is applicable to all civilian sites (not just transportation sites) and focuses on the effect and role of transportation during such an event.

This Report contains four products developed under NCHRP Project 20-59(19):

1. Technical information is presented on chemical, biological, and radiological threats, including vulnerabilities of the transportation system to these agents and consequence-minimization actions that may be taken within the transportation system in response to events that involve these agents. The threat–related section of the Report presents the fundamentals of chemical, biological, and radiological agents; describes the basic information needed for emergency response decisions; discusses how chemical, biological, and radiological threats relate to transportation-system vulnerabilities and consequence-minimization actions; and generally compares the different threat-agent categories. The transportation section of the Report describes each of the transportation modes (i.e., highway, maritime, rail, aviation, and mass transit); their general organization; and their mode-specific emergency response plans, options, and structure.
2. Tracking Emergency Response Effects on Transportation (TERET) is a spreadsheet tool structured to assist transportation managers with recognition of mass-care transportation needs and identification and mitigation of potential transportation-related criticalities in essential services during extreme events. TERET is intended to be used as a guide during emergency response planning stages as well as during an emergency response exercise or actual event. The primary users are expected to be transportation planners and managers at emergency management centers.
3. The User's Manual for TERET is printed at the back of the Report. It provides step-by-step instructions on the use and maintenance of TERET.
4. An Introduction to Biological, Chemical, and Radiological Threat Agents is a slide presentation with presenter notes in MS PowerPoint. It is designed as an executive-level communications tool based on summary information from this report. Like the Report, TERET, and the User's Manual for TERET, the slide presentation is available on the TRB website.

These materials should be helpful to transportation agencies in creating or evaluating and modifying emergency response plans, policies, and procedures consistent with the National Incident Management System (NIMS). The importance of NIMS is set out in a September 8, 2004, letter to state governors, from Department of Homeland Security Secretary Tom Ridge: "NIMS provides a consistent nationwide approach for Federal, State, territorial, tribal, and local governments to work effectively and efficiently together to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size, or complexity."

Science Applications International Corporation prepared this volume of *NCHRP Report 525* under NCHRP Project 20-59(19).

Emergencies arising from terrorist threats highlight the need for transportation managers to minimize the vulnerability of travelers, employees, and physical assets through incident prevention, preparedness, mitigation, response, and recovery. Managers seek to reduce the chances that transportation vehicles and facilities will be targets or instruments of terrorist attacks and to be prepared to respond to and recover from such possibilities. By being prepared to respond to terrorism, each transportation agency is simultaneously prepared to respond to natural disasters such as hurricanes, floods, and wildfires, as well as human-caused events such as hazardous materials spills and other incidents.

This is the tenth volume of *NCHRP Report 525: Surface Transportation Security,* a series in which relevant information is assembled into single, concise volumes—each pertaining to a specific security problem and closely related issues. These volumes focus on the concerns that transportation agencies are addressing when developing programs in response to the terrorist attacks of September 11, 2001, and the anthrax attacks that followed. Future volumes of the reports will be issued as they are completed.

To develop this volume in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources, including a number of state departments of transportation. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data and to review the final document.

This volume was prepared to meet an urgent need for information in this area. It records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. Work in this area is proceeding swiftly, and readers are encouraged to be on the lookout for the most up-to-date information.

Volumes issued under *NCHRP Report 525: Surface Transportation Security* may be found on the TRB website at http://www.TRB.org/SecurityPubs.

CONTENTS

A GUIDE TO TRANSPORTATION'S ROLE IN PUBLIC HEALTH DISASTERS

SUMMARY

This report contains introductory information on chemical, biological, and radiological (CBR) threats as they relate to the transportation system. The report presents the fundamentals of CBR agents, describes the basic information needed for emergency response decisions, discusses how CBR threats relate to transportation system vulnerabilities and consequence minimization actions, and generally compares the different threat-agent categories. The transportation section describes each of the transportation modes (i.e., highway, maritime, rail, aviation, and mass transit), their general organization, and their emergency response plans, options, and structure.

Incident response to a CBR release probably will involve establishing isolation and restriction areas where dangerous contaminant levels are suspected. The extent of such areas often will change as a more thorough survey of contaminant levels is conducted. In general, the speed with which CBR contamination can be identified affects the duration of broader, initial restricted areas and related requirements for suspension of transportation service and traffic re-routing.

Chemical and radiological agents can be identified rapidly with portable detectors. In contrast, only a few types of biological agents can be identified with portable detectors. For most biological agents, identification takes several days of laboratory analyses. The longer time usually required for identifying the extent of biological contamination means isolation and restriction areas will be delineated with a wider margin of uncertainty incorporated into the restricted area to ensure safety.

Non-persistent CBR agents (e.g., industrial gases, sarin, and many vegetative bacteria and viruses) typically do not pose a substantial threat for more than a day or two unless there is a continual source of release. In contrast, persistent agents have the potential to cause greater disruption of transportation because of the longer period over which they pose a substantial threat.

Suspension of transportation services because of a CBR release is determined largely by the duration of decontamination. CBR agents that are not persistent may naturally degrade or disperse to safe levels within hours to days (e.g., industrial gases, sarin, and many vegetative bacteria and viruses) and thus may not require active efforts for decontamination. Although many chemical and biological agents are relatively easy to decontaminate, decontamination methods that involve applying

chemicals such as bleach solutions can also destroy property (e.g., carpet and upholstery), and extend the total reclamation period. For persistent chemicals (e.g., mustard and VX) and biological agents (e.g., anthrax and mycotoxins), decontamination is likely to take days to months. In general, radiological agents are the most persistent and difficult to decontaminate. Decontamination of a radiological release is likely to take months to years.

Table S-1 (the same as Table 2-16) summarizes the transportation system's vulnerabilities with respect to the system's ability to retain contamination of persistent CBR agents at levels that may affect human health, the difficulty of decontamination, and the ability to spread these contaminants.

In enclosed areas (e.g., passenger compartments and buildings), the ventilation system may help in dispersing CBR agents, thus shutting down these systems is a commonly recommended first response. In open, outdoor areas, concerns about wind spread of contamination may be off set by factors such as wind ability to enhance evaporation of liquid agents and broadly dilute vapors and small particles to safe levels and sunlight degradation of many chemical and biological agents. These same factors may help decontamination of chemical and biological agents in open environments; however, runoff control of decontamination chemicals may be more challenging.

TABLE S-1 Relative Vulnerabilities of the Transportation System to Releases of Persistent Chemical, Biological, and Radiological Agents. (Persistence = more than 24 hours to substantially degrade in an open environment)

Vulnerability	Ability to Retain Contamination			Difficulty of Decontamination			Ability to Spread Contamination		
	Chem[1]	Bio[2]	Rad[3]	Chem[1]	Bio[2]	Rad[3]	Chem	Bio	Rad
Transportation Path									
Road	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Track	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Tarmac	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Air	Low	Low	Low	Low	Low	Low	High[4]	High[4]	High[4]
Waterway	Low	Low	Low	Low	Low	Low	High[4]	High[4]	High[4]
Indoor or Underground Stations/ Terminals									
Smooth surfaces	High	High	High	Medium	Medium	High	Low	Low	Low
Porous surfaces[5]	High	High	High	Medium	High	High	Low	Low	Low
HVAC system	Medium	Medium	Medium	Low	Low	Low	High	High	High
Outdoor Stations/ Terminals									
Smooth surfaces	Medium	Medium	High	Low	Low	Medium	Low	Low	Low
Porous surfaces[5]	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Vehicles/ Vessels									
Smooth surfaces	Medium	Medium	Medium	Low	Low	Medium	Low	Low	Low
Porous surfaces[5]	High	High	High	High	High	High	High[6]	Medium	Medium
HVAC system	Medium	Medium	Medium	Low	Low	Low	High	High	High
Contents									
Crew/ Passengers	Medium	Medium	Medium	Medium	Medium	Medium	High[6]	Medium[7]	Medium
Cargo/ food/ water	High	High	High	Medium	Medium	High	High	High	High

[1] Persistent chemicals include some chemical weapons agents (e.g., mustard agents, VX). Most transported industrial chemicals and many chemical agents are not persistent; thus ability to retain contamination and the difficulty of decontamination is low for many chemicals due to their non-persistence.

[2] Persistent biological agents include Anthrax spores, mycotoxins (T2 or yellow rain), and the causative agent of Q-fever, none of which are very contagious. Most other biological agents are not persistent in an open environment, and the ability to retain contamination and the difficulty of decontamination would be relatively low.

[3] Most radiological agents are persistent. For those that are not persistent the ability to retain contamination and the difficulty of decontamination would be relatively low.

[4] Ability to spread contamination is high, but the contaminant may be relatively quickly diluted below levels of concern.

[5] Porous surfaces include corroded metal, cement, rubber, carpet, fabric, etc.

[6] Most persistent chemical agents of concern (i.e., mustard and VX) are oily liquids that may adhere to skin, clothing, and other porous surfaces better than solid particle forms of radiological and biological agents.

[7] High if the biological agent is contagious (i.e., influenza, pneumonic plague, smallpox, some hemorrhagic fevers).

In general, porous surfaces have greater ability to retain contamination than smooth surfaces. Porous surfaces such as fabric, rubber, and corroded metal have microscopic pits and valleys that may retard natural degradation and hinder decontamination efforts.

After decontamination, the only CBR agents that may be spread further are the subset of biological agents that are contagious. For many diseases, the most contagious stages occur during the period that infected individuals are obviously sick and often confined to bed. The transportation system may make easier the dispersal of infected individuals before contagious stages, in addition to the possibility of contagious passengers infecting other passengers.

Five modes are considered within the national transportation system: highway, maritime, rail, air, and mass transit. Controlling agencies for each these modes, along with their emergency response organization and general historical emergency response activities can suggest how these resources may be used in future events and what organizations may be involved in developing mutual assistance agreements.

About 77 percent of the highway system is owned by local governments, 20 percent by states, and 3 percent by the federal government. Emergency response plans for highways are developed by state departments of transportation (DOT). These plans address emergency response modification of traffic flow, determination of roadway soundness, and provision of trucks and personnel per the request of incident command. Counties and municipalities also have transportation and emergency response offices with plans that like the state DOT plans, are for emergency re-direction of traffic passing on their roadway. Thus, during an emergency, the primary entities for activating emergency response that affect the highway system are state and local governments.

There are about 150 deep-draft ports in the US. These are overseen by state and local port authorities, with the primary objective of promoting commerce. There are significantly more shallow-draft ports, which are run by local governments and commercial entities. Regardless of port, vessel size or ownership, the US Coast Guard (USCG), has primary responsibility for safety and emergency response over the nation’s waterways and in its ports. The USCG develops Area Security Plans that address emergency operations. During emergency events, temporary ferry lines have been established to supplement other compromised transportation modes and assist in evacuations. Many large tugboats are equipped to assist with firefighting needs, and various pubic and private vessels have assisted with search and rescue operations. The primary entity for activating emergency response activities that affect the maritime system is the USCG.

More than 90 percent of freight railroads, including rail track, are privately owned and operated. While there are only 8 large, Class I carriers that operate 68 percent of the track, there are more than 500 smaller railroads. The activities of these companies are coordinated through the America Association of Railroads (AAR), which maintains a single-point database of rail shipments through Railinc. Decisions about emergency changes in security and operations are typically made at a corporate level, where there are rotating shifts, around-the-clock, of top decision-makers. During emergency response events, resources provided by railroads have included use of freight cars, shipping of supplies free of charge, and increasing on-duty staff as needed to meet emergency shipping needs. The single-point contact for initiating emergency response activities that affect the rail system is the AAR, which in turn, can quickly identify the appropriate organizations for the region, and assist in the coordination of traffic among various carriers.

The air transportation system consists of three segments, each with different types of ownership. Airports are typically owned and operated by state or local governments. Aircraft are primarily owned by commercial and private entities. Communications, navigation, and the air traffic control (ATC) system are primarily owned by the federal government. The Federal Aviation Administration (FAA) has released an advisory for "State and Regional Disaster Airlift (SARDA) Planning." SARDA may be developed and implemented by a state or regional DOT, or office of aviation, its resources may include those within state and local governments, the Civil Air Patrol, and other volunteer organizations of commercial and private operators such as the Emergency Volunteer Air Corp (EVAC), etc. When a state emergency is declared, National Guard resources are available; and when a national emergency is declared, more resources may be provided by the Civil Reserve Air Fleet (CRAF) and the US Department of Defense (DOD). Not all states have developed a SARDA plan. In these cases, the Civil Air Patrol may provide the first line of aviation support. Aircraft and helicopters may transport supplies, first-responders, and evacuees. Limitations are typically not with aircraft availability, but rather with airport capacity.

The mass transit systems predominantly are owned and operated by county, city, or metropolitan area governments. Some transit service is provided by private entities, often in affiliation with local mass transit agencies. All transit agencies have some level of emergency plans that often include preset alternate routes and schedules to allow them to move around problem areas and to provide assistance to first-responders as needed. The 30 largest public transit agencies have plans that specifically address weapons of mass destruction. Emergency response decisions in mass transit organizations are typically made at the operations level. In addition to re-routing around isolation areas and assisting with evacuations, mass transit vehicles may be modified to assist with transport of supplies. In general, emergency response decisions follow pre-set plans that can be superseded by the incident command. These actions do not require explicit consultation or approval within the transit agency beyond the operations division.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The overall objective of this project was to develop a guide to help transportation managers develop transportation response options in the case of an extreme event. This report is one part of this project and supports the overall project goal by providing background information to assist in transportation planning for chemical, biological, and radiological (CBR) events. This document describes the key features of CBR threats, and transportation responses to these threats; and provides an overview of the primary modes in the transportation system (i.e., highway, maritime, rail, aviation, and mass transit) including emergency response organization.

1.2 AUDIENCE

This report is directed primarily toward those in the emergency response community with a collective interest in transportation incident management (i.e., emergency response). General managers, middle to upper-level managers, transit security, and community emergency response managers constitute the target audience for this report.

1.3 SCOPE

The scope of this report includes the following:

- Extreme events involving CBR agents where extreme events are defined as those that may have at least a city-wide effect.
- Introduction to the fundamentals of CBR events, including the general types of events; categorization of the threats; and general introduction to the doses, detection, and decontamination of these threat agents.
- Specific address of the information needed for emergency response decisions during a CBR event and the transportation system vulnerabilities and actions for consequence minimization of CBR events.
- General description of each of the primary transportation modes on a national level including system size, use, financing, and general organization.
- General description of each of the primary transportation modes emergency plans and organization, and historical emergency actions.

1.4 LIMITATIONS

The information in this report is general, with some specific examples. Although the concepts presented should be helpful in dealing with a CBR event, the details of the specific threat agent and the scenario of its release (including location, quantity, and meteorology) will dictate the most appropriate specific responses.

CHAPTER 2

TRANSPORTATION RESPONSE TO CBR EVENTS

This section summarizes the key characteristics of CBR threats (Sections 2.1, 2.2, and 2.3) and then compares these agents (Section 2.4). Sections 3.1, 3.2, and 3.3 focus on threat characteristics that will affect the selection of transportation response options and the development and implementation of a transportation response plan. Each of the threat-specific sections includes

- A fundamental description of the threat,
- Information needs for emergency response decision-makers, and
- Discussion of transportation system vulnerabilities to the threat agent and consequence minimization.

Section 2.4 compares the general categories of CBR agents with respect to factors that decide their potential effects on the transportation system. Readers are encouraged to review multiple information sources for better understanding of CBR threats. Because any given source may be very helpful and accurate in many aspects and still have some misleading presentation of factual details, it is important to recognize the general level of information presented and that overall summaries often must generalize for the sake of simplicity and omit qualifying details (e.g., with respect to persistence in specific types of environments, lethality or contagiousness of particular strains, etc.). For another general source for an introduction to CBR threats is The National Academies Fact Sheets on Terrorist Attacks, available on line at

http://www.nae.edu/nae/pubundcom.nsf/weblinks/CGOZ-642P3W?OpenDocument

2.1 CHEMICAL THREATS

Familiarity with the basic types of chemicals that may pose threats can aid in developing appropriate emergency response plans. The effects of toxic chemical releases range from irritations to fatality. The chemical agents addressed in this report are those that react chemically with the cells of the human body to cause adverse effects. Types of chemicals not included in this report are those that pose their greatest threat by displacing substantial amounts of ambient oxygen during a large release, thereby causing asphyxiation (e.g., methane, nitrogen, carbon dioxide), and flammable agents (i.e., incendiaries), which are most likely to cause harm by burning and creating large amounts of heat (e.g., napalm and ethylene oxide).

This section discusses chemical fundamentals (2.1.1), emergency response information needs (2.1.2), and interrelationships among chemical threats and the transportation system (2.1.3).

2.1.1 Fundamentals

Some background information can help in understanding chemical threats. The fundamentals addressed in the subsections below are

- Basics,
- Events,
- Categories,
- Doses,
- Detection, and
- Decontamination

More information on chemicals is readily available from many sources, including the Internet. Some of these sources are listed in Appendix A.

Basics

Thousands of different chemicals pose different threats to humans. Some basic concepts and associated terms used in evaluating a specific chemical toxin are as follows:

- Toxicity. This is a measure of the quantity of a substance required to get a harmful effect. Depending on the type of harmful effects cause by the chemical, a highly toxic chemical may or may not be likely to cause death.
- Lethality. This refers to how much of a substance is needed to cause death. Not all chemical weapons are designed to maximize lethality (e.g., riot-control agents, which are designed to incapacitate, but not kill, the target).
- Exposure route. Exposure routes are the pathways by which a chemical may enter the body. The most common

exposure route for both chemical weapons and an industrial chemical release is inhalation, followed by skin absorption. The final exposure route, ingestion, may occur with contamination of food and water supplies and to a much lesser extent with inhalation of particles.

- Speed of action. This refers to the delay between exposure to a toxin and the beginning of symptoms, which varies from split-seconds to hours.
- Persistence. This refers to the length of time the chemical remains toxic after release. Loss of toxicity may be caused by dilution, as when a gas is dissipated by the wind, or chemical breakdown from various chemical reactions that may occur with water, oxygen, and light. The military defines a chemical as non-persistent if it is likely to evaporate or break down from a ground surface in less than 24 hours at temperatures of 60 to 80 °F. Most if not all, commercial chemicals carried in bulk (e.g., chlorine, ammonia, and hydrogen fluoride) are non-persistent.
- Dose. A dose is the amount of a chemical taken into the body and depends on the chemical concentration, the duration of exposure, and the route of exposure. The quantity of a chemical needed for a dose to yield harmful effects depends on the chemical toxicity and the exposure route.

Events

From an emergency response perspective, understanding where, what type, and how much chemical contamination has been released are the key issues for decision-making in the event of a chemical threat. The cause of the chemical release is, in many cases, likely to be a secondary issue for response management unless it suggests an increased possibility of a second release. However, recognition of the types of chemical events that may occur can assist in both assessing regional vulnerabilities and in developing scenarios for emergency training and exercises. Two basic types of chemical releases are described below.

- Chemical Infrastructure Event. Chemicals may be released from any of the thousands of facilities in the United States that produce, handle, use, and store chemicals, or chemicals in transport between these facilities. Two types of release events that have received substantial attention and response planning are
  - Chemical plant incident—involves the accidental or deliberate release of dangerous levels of chemicals from one or more of the 66,000 chemical facilities in the United States. The FBI has long warned that attacks on an industrial facility may come from a local or disgruntled employee, just as the 1984 Bhopal incident appears to have been a result of human error or sabotage by a demoted employee. In an extreme event, such as occurred in Bhopal, India, a radius of tens of miles and the health of many thousands of people may be threatened.
  - Chemical transportation incident—refers to an accidental or deliberate release of chemicals that are in transport. Large quantities of chemicals are transported in special containers, which, if breached, can result in a significant chemical release. This may occur inadvertently, such as in the case of the recent (February 2004) runaway train in Iran, which derailed and released sulfur, petrol, and fertilizer before an explosion that killed more than 300 onlookers. In a deliberate release, a vehicle or vessel may be attacked or hijacked and driven to a densely populated area before the chemical release to maximize injury and destruction.
- Chemical Weapons Event. Refers to the use of chemical weapons agents that may have been produced by a government or by terrorist organizations. Precursors for the chemical weapons may be obtained legally or illegally. Large quantities of chemical weapons are more difficult to obtain than industrial chemicals, thus releases of chemical weapons in crowded enclosed spaces (e.g., subway or airport), where a small amount may be effective is a more likely terrorist scenario than an open-air release.

In general, a serious chemical event may result in hundreds to a few thousand casualties and in thousands of permanent injuries. As large as the magnitude of these consequences seems, it is not as great as could occur from a serious radiological or biological event, which are addressed in other sections of this report.

Categories

Many methods exist for grouping or categorizing the many thousands of chemicals available. OSHA and DOT use a similar classification of chemicals based on the type of physical hazard posed (e.g., explosives, flammable liquids, and corrosives).[1] The OSHA/DOT classification system typically is used to describe chemicals involved in chemical infrastructure incidents, either at a chemical facility or during transport. However, when chemicals are intentionally used to threaten people, they are referred to as chemical weapons and spoken of in terms of their military classification. The military classification system is based on the human symptoms the agent causes (e.g., choking, blister, and nerve). Many of these weapons classes were first used in World War I. The most common classes of chemical

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[1] The Department of Transportation Emergency Response Guidebook, 2004, describes this classification system and can be viewed or downloaded from links provided at http://hazmat.dot.gov/pubs/erg/gydebook.htm

weapons that have proliferated since WWI are described below:

- Choking agents. Inhalation is the typical exposure route for choking agents, also called "respiratory" or pulmonary" agents. They are lung irritants that cause fluid build-up in the lungs, which can result in suffocation as much as 24 hours after exposure. Although choking agents are no longer common as military weapons, many choking agents are common industrial chemicals, and their release from an industrial facility or during bulk transport can have devastating effects. Historically, chlorine and phosgene have been the most used chemical weapon choking agents and are currently mass-produced by the chemical industry. Some choking agents are gases at standard temperature and pressures (e.g., chlorine and phosgene); others are liquids that are most dangerous as aerosols (e.g., diphosgene). Choking agents generally dissipate relatively easily under many open-air circumstances so typically are not persistent.
- Blister agents. These agents cause serious skin and eye irritation. Blister agents, also referred to as "vesicants," are the most widely used and stockpiled chemical weapon. Although blister agents can cause death, they are not considered very lethal. They are used primarily to cause substantial distress, put demands on the medical system, and incite general public fear. Blister agents include sulfur mustard, nitrogen mustards (e.g., HN-3), and Lewisite. They are low-cost and relatively easy to mass produce. Although eye irritation often occurs within minutes, the development of noticeable skin irritation varies from seconds for Lewisite, to hours for mustard agents. Many blister agents will persist on surfaces for days in the summer and, depending on the temperature, may persist for weeks in the winter. In soils, persistence may be longer. Blister agents can seep through fabric, rubber, and leather, so first-responders and decontamination crews require special protective clothing.
- Nerve agents. These organophosphate chemicals are liquids at standard temperatures and pressure. Exposure routes are inhalation and skin contact, depending on the dispersion method (i.e., size of aerosol droplets), and their rate of evaporation after settling. Nerve agents paralyze the respiratory muscles and can cause death within a few minutes when inhaled, whereas a drop on unprotected skin may take several hours to produce severe symptoms and possible death. Some of the more common chemical weapon nerve agents are sarin, tabun, soman, and VX. They vary in persistence from a few hours for sarin to days or weeks on surfaces (i.e., potential skin exposure) for agents such as VX. Nerve agents require more sophistication to produce than blister agents, but have been produced and used by terrorists (i.e., sarin was used in 1995 by the Aum Shinrikyo cult in Tokyo). Some nerve agents have been used along with blister agents for a broader scope of effects.
- Blood agents. These toxins typically are taken into the body by inhalation and act by blocking oxygen use or uptake from the blood, thereby causing suffocation. Hence, blood agents are also called "chemical asphyxiants." Some of the more common blood agents are hydrogen cyanide (the active ingredient in Zyklon B), hydrogen sulfide, and cyanogen chloride. These agents are highly volatile and difficult to store and have a low persistency on release. However, they are also very lethal and act very quickly. Agents such as hydrogen cyanide are easily produced from common industrial chemicals and therefore may attract terrorist interest.
- Riot-control agents. These include pepper sprays and tear gases (e.g., CS and CN, both of which are actually solids at standard temperature and pressure). They irritate the eyes, nose, and mouth, initially mimicking other chemical weapons agents. CS is favored for large-scale riot control because of its low toxicity and short-term effects (5 to 15 minutes). Although they are not generally lethal unless ingested in high doses, riot control agents can cause extreme discomfort and panic, which can lead to lethal events. Furthermore, in enclosed areas, fine particles from some riot control agents may facilitate explosions similar to grain elevator explosions.

Other, less common chemical weapons classes include vomit agents and incapacitants (i.e., psychoactive chemicals). Non-toxic chemical agents, such as obnoxious odorants, can be used to harass or mask other toxic compounds. In recent years there have been more than one hundred cases of "noxious chemical vandalism" on abortion clinics throughout the United States. The chemical agent in these events was butyric acid, which produces a rancid butter odor, can irritate skin and eyes, and requires much effort to remove the odor. With the classification of these cases as vandalism, terrorism experts generally believe that nerve and blister agents are the most likely chemical weapons to be used by government-defined terrorists.

In addition to chemical weapons agents, numerous industrial chemicals at both fixed sites and during transport may be attractive to terrorists. Based on available sources, FBI investigations, product availability, and the complexity of manufacture and development, the FBI has developed a list of industrial chemicals potentially attractive to terrorists (Table 2-1). Appendix A contains a list of other organizations that have similar lists of chemicals of concern and a summary table of specific characteristics of several potential chemical agents

TABLE 2-1 FBI Community Outreach Program List of Potentially Attractive Chemicals for Terrorist and Criminal Activity

Ammonia	Arsenic	Arsine
Boron Trichloride	Boron Trifluoride	Butyric Acid
Carbon Disulfide	Chlorine	Chloroacetone
Cyanides	Diborane	Dimethyl Sulfate
Dimethyl Sulfoxide (DMSO)	Ethylene Oxide	Fluorine
Formaldehyde	Hydrogen Bromide	Hydrogen Chloride
Hydrogen Fluoride	Hydrogen Sulfide	Mercury
Methyl Phosphonyl Dichloride	N,N'-Dicyclohexyl carbo-dimide (DCCDI)	N,N'-Diisopropylcarbo-diimide (DICDI)
N,N'-Dimethylamino Phos-Phoryl Dichloride	Nitric Acid	Phosphine
Phosphorus Trichloride	Sodium Azide	Sodium Fluoroacetate
Sulfur Dioxide	Sulfuric Acid	Thallium
Thiodiglycol	Thionyl Chloride	Tributylamine
Tungsten Hexafluoride	2-(Diisopropylamino) ethane thiol	2-(Diisopropylamino) ethanol

Reproduced from the FBI Community Outreach Program for Manufacturers and Suppliers of Chemical and Biological Agents, Materials, and Equipment (http://www.aiche.org/ccps/pdf/fbi_wmd.pdf). This list is by no means complete. Other lists of potentially attractive chemicals are provided in Appendix A.

Doses and Concentrations of Concern

The specific dose of a chemical that is received is not easily measured, unless the chemical is given in a carefully measured way. This is because the amount of a chemical taken into the body can vary among individuals. For example, the dose received of a blister agent may vary with the type of clothing an individual is wearing. Therefore, exposure to chemicals in the environment is often discussed in terms of exposure concentrations rather than doses.

Chemical concentrations of concern vary depending on the situation being addressed. For example, in an office workplace, the amount of ozone that causes 50 percent of the employees to have burning eyes for several hours every workday is a serious issue. However, in a chemical weapons event, this same effect is not generally considered serious (although the event may be considered serious as an indication of possible future, more harmful events). The many different concentrations of concern for chemicals reflect the differences in levels of effect that are a concern.

Concentrations of concern are based on a specific effect (e.g., discomfort, serious injury, or death), within a specific time (e.g., immediate, 10 minutes, 96 hours), in a specific percentage of the population (e.g., 1 percent, 10 percent, or 0 percent). Concentrations of concern are established by government agencies (e.g., OSHA, DOE, or EPA) and industry associations on the basis of multiple studies. In a chemical release event, concentrations that cause long-lasting health effects from short-term exposures are a primary reference for response management. Table 2-2 displays concentrations as parts per million (ppm) of several chemicals. The concentrations shown are Acute Exposure Guideline Limits (AEGLs) established by EPA. AEGL-2 concentrations are airborne concentrations above which the general population could experience irreversible or long-lasting serious health effects, or an impaired ability to escape. AEGL-3 concentrations are airborne concentrations above which the general population could experience life-threatening health effects or death. The smaller the AEGL, the smaller the amount of the material that needs to be released to cause dangerous health effects to people within a given area. Appendix A describes other chemical concentrations of concern.

Chemical Detection

Identification of chemicals involved in chemical infrastructure incidents can often be determined from OSHA- and

TABLE 2-2 Examples of Acute Exposure Guidelines for Inhalation

Chemical	AEGL-2 (ppm)			AEGL-3 (ppm)		
	10 min	1 hr	8 hr	10 min	1 hr	8 hr
Ammonia	270	110	110	2,700	1,100	390
Chlorine	2.8	2.0	0.71	50	20	7.1
Hydrogen Cyanide	17	7.1	2.5	27	15	6.6
Sarin	0.015	0.006	0.002	0.064	0.022	0.009
Sulfur Mustard	0.09	0.02	0.002	0.59	0.32	0.04

(Source: EPA's National Advisory Council/AEGLs website at ***http://www.epa.gov/oppt/aegl/chemlist.htm****)*

DOT-required labeling and tracking. In a chemical facility incident, first responders may be able to identify the chemical based on community preplanning lists of hazardous chemicals at specific locations. In addition, emergency personnel should be alert to other obvious locations in their communities that use hazardous materials, such as laboratories, factories, farm and paint supply outlets, and construction sites.

In a chemical transportation incident, cargo chemical identity can be determined from

- Container Shape. DOT regulations dictate certain shapes for transport of hazardous materials.
- Markings. Transportation vehicles must use DOT markings, including identification (ID) numbers, located on both ends and sides of all cargo tanks, portable tanks, rail tank cars, and other small packages that carry hazardous materials.
- Placards and Labels. These convey hazard class information by use of colors and symbols, and either hazard class wording or four-digit identification numbers. Placards are used when hazardous materials are in bulk such as in cargo tanks; labels designate hazardous materials on small packages.
- Shipping Papers. These provide the same information as on placards and labels. Such papers also provide to the shipper name, quantity of material, and general emergency response instruction. Shipping papers must accompany all hazardous material shipments.
- Senses. Odor, vapor clouds, dead animals or dead fish, fire, and irritation to skin or eyes can signal the presence of hazardous materials.

After a chemical has been identified, information on how to respond can be found in various references, such as Material Safety Data Sheets (MSDS), the DOT Emergency Response Guidebook, and the CHEMical TRansportation Emergency Center (CHEMTREC) web page (http://www.chemtrec.org/Chemtrec/), in addition to the shipping papers.

Thus, there are several sources of on-scene information for chemical events involving a chemical facility or chemical transportation. In contrast, none of this information would be available during a chemical weapons event. Regional HazMat teams should be equipped with Technical Operations Modules, or science and control units that contain chemical detection equipment such as chemical detector system kits; programmable chemical agent detectors; and M256A1 Chemical Agent Detector Kits. HazMat teams may also have multigas meters, organic vapor analyzers, and gas chromatograph/mass spectrometers. If the HazMat team cannot identify the chemical in question, the incident commander probably will be able to call on the services of local laboratories (e.g., in universities) for assistance. These various detectors can also be used during chemical facility and chemical transportation incidents.

Chemical Decontamination

The need for decontamination of chemical agents depends on their concentration and persistence. There is no generally accepted guide on large-scale chemical decontamination methods. Thus, when persistence is long enough to consider active decontamination, controversy is likely. The trade-off between passive decontamination (i.e., isolating the contaminated area and allowing the contaminant to degrade or become diluted naturally) and active decontamination (i.e., taking action to degrade or dilute the contaminant to safe levels) will be affected by the location and size of the contaminated area, the affected population and economy, and the persistence of the chemical agent and the hazards associated with decontaminating agents (e.g., chlorine).

Blood agents such as hydrogen cyanide, arsine, and cyanogen chloride are chemical asphyxiants that evaporate rapidly in the environment, generally precluding the need for decontamination actions. In enclosed conditions where decontamination may be needed, both respiratory support and protective clothing are needed, because these agents may also be absorbed through the skin and eyes.

In contrast, blister agents are very persistent at cold temperatures. However, at warmer temperatures, evaporation rates increase causing higher vapor concentrations that present inhalation as well as skin absorption hazards. Many of these agents are inactivated gradually by sunlight, increasing the rate of their degradation in outdoor versus indoor environments. There are exceptions however, Lewisite is both stable below about 120 °F and is not inactivated by sunlight. The primary mode for active decontamination of blister agents has been copious amounts of water with a 0.5% hypochlorite solution (1 part bleach, 9 parts water). Protective respiratory support and clothing must be worn by trained personnel. Phosgene oxime is unique among the blister agents in that it may be chemically inactivated using an alkali.

Nerve agents such as sarin, soban, and tabun evaporate and loose their toxicity within minutes to days, depending on temperatures. The need for active decontamination is increased for nerve agents that are slower to evaporate (i.e., soman, GF, and VX). For active decontamination of nerve agents, water has been used. Nerve agents are organophosphates, which is the same chemical family as many common pesticides (e.g., chlorpyrifos, diazinon, disulfoton, malathion, sevin, etc), thus water run-off containing these agents may pose hazards for both environmental and human health.

Both nerve and blister agents may be thickened into an oily liquid that can remain on surfaces as a persistent hazard. When the agents are thickened, a soap and bleach solution is used. In both cases, protective clothing and respiratory protection are needed during the clean-up.

The use of large quantities of chlorine (i.e., bleach), in particular, may be subject to EPA and similar state requirements. These requirements may include containment of runoff, measurement of water quality, and possible sustained holding of run-off water with more treatment until acceptable levels of both the initial contaminant and any added decontaminants (i.e., chlorine and soap) are reached.

2.1.2 Emergency Response Information Needs

Regardless of the cause of a chemical release, from an emergency response perspective, the primary considerations for response management are the chemical type and toxicity, quantity and persistence, exposure route; and dispersion and population density in the area at risk. These factors and their interrelationship are discussed below. Table 2-3 delineates some of the information needed in a chemical event to decide the appropriateness of transportation goals for isolation, shelter-in-place, evacuation, and checkpoint establishment.

Chemical Type and Toxicity

Chemical type and toxicity are key factors in assessing the threat posed to human health, thus is important for determining appropriate protective wear for first-responders and clean-up personnel, and population risks. The health risks to responders and the general population are also affected by the contaminant concentration (derived for the initial quantity and area of dispersion) and the exposure route. In populated areas, the general type of a released chemical can often be assessed within minutes of release because of the rapid onset of symptoms. Most industrial transport chemicals are choking agents or asphyxiants. In non-industrial events, multiple agents may be released, and a more common agent, such as tear gas, initially may mask the presence of another agent, such as the blister agent mustard gas, for which symptoms other than those similar to tear gas may be delayed for several hours.

TABLE 2-3 Determination of Chemical Event Emergency Response

Chemical Event
Information Needed to Determine Appropriate Emergency Response
Estimated ***population exposed*** to levels of concern as determined from: ◆ Affected area information *(see below)* ◆ Population data
Estimated ***affected area*** as determined from: ◆ Quantity and toxicity of material ◆ Release parameters (density, temperature, momentum, etc.) ◆ Location of release ◆ Wind direction and speed ◆ Topography, urban or rural environment ◆ Levels of concern (i.e., toxicity)
Possible ***exposure pathways*** as determined from: ◆ Chemical identity ◆ Physical form (gas, liquid, solid)

Quantity and Persistence

The quantity of a chemical released and the chemical type and toxicity determine the potential human health effects. The quantity and persistence of the released chemical determine the duration of the human health risk. An upper range estimate of the quantity of a chemical release from an industrial storage or transport container can be determined easily on the basis of container size and can assist in developing a conservative estimate of the area that may receive concentrations of concern. The larger volumes of chemicals in transport are in railcars, with amounts up to 90 tons per car, and on inland and coastal barges in amounts up to 2,500 tons per barge. These containers may be particularly attractive from a terrorist perspective because of the possibility of very quickly releasing large quantities of a toxic chemical. Toxic gases (transported as both gases and as liquids under pressure) are generally not very persistent, so typically present only a short-term threat.

Estimating the release quantity and associated area with concentrations of concern may be more problematic from a chemical weapons release, particularly if there is a delay between exposure and observable symptoms. Particularly among blister and nerve agents, the persistence of chemical toxicity after release varies greatly (i.e., from minutes to weeks). The identification of a chemical weapons release agent needs to be confirmed with laboratory tests to estimate confidently its persistence and the protective wear needed during clean up.

Exposure Route

Possible exposure routes are determined by whether the chemical is a gas, liquid, or solid. If it is one of the latter two forms, aerosol or particle size and evaporation rate must also be considered. Inhalation is the primary exposure route of concern for choking agents and for some nerve agents (e.g., sarin). In a severe release, inhalation may also be an important exposure path for some blister agents. The time required for an agent suspended in air to be diluted, and for particles and aerosols to settle to the ground and evaporate, determines how long inhalation is a concern. The size of the particles is critical in that if the particles are too large, they quickly fall to the ground and no longer pose a threat through the inhalation exposure route. Table 2-4 provides estimates

TABLE 2-4 Particle Size and Sedimentation Rate in Stagnant Air

Particle Diameter	Time to Fall 100 Ft.
100 microns	2 minutes
10 microns	3 hours
3 microns	30 hours
1 micron	240 hours
0.5 microns	820 hours

of how long it takes various particle sizes to settle to the ground when there are no wind currents.

The smaller the particle, the further it may travel within the respiratory tract. In general, particles greater than 10 μm (micrometers, also called microns) in diameter are trapped by nasal hairs and released with exhaled air or sneezing. Particles less than 10 μm in diameter are referred to as "inhalable" because they may pass into the upper portions of the lungs, which contain many branched passageways. These passages (bronchi and terminal bronchioles) are lined with mucus and cilia. The mucus traps particles, and the cilia gradually push the mucus and its contents up and out of the lungs within about a day. Chemical agents trapped in the mucus are then swallowed, entering the digestive tract. The smallest particles or aerosols (e.g., less than 2.5 μm diameter) are referred to as "fine" or "respirable" particles. Fine particles may pass into the deepest portions of the lungs (i.e., respiratory bronchioles, alveolar ducts, and alveolar sacs) where they may dissolve or be removed by macrophages over many days.

The unaided human eye can discriminate individual particles down to the size of 30 microns. These particles will be trapped by nose hairs and mucous and blown out or swallowed before reaching the lungs. To put particle sizes in perspective, particle size of commonly used substances are presented in Table 2-5.

Absorption through skin is the primary exposure route for some chemical weapons agents (i.e., essentially all blister agents and some nerve agents). Many of the agents for which the skin is a primary exposure route are oily liquids. Aerosol droplets too large to be readily respired are a common means for dispersal of these agents. Droplets of some of these agents (e.g., VX) can take weeks to evaporate or break down to less toxic forms. Many common fabrics provide protection from skin absorption of some agents (e.g., the blister agent phosgene oxime), but provide little protection from other agents (e.g., sulfur mustard).

Ingestion of chemical toxins may occur with tainted drinking water or food. An effective chemical toxin release in the drinking water supply of a city-sized population generally is not viewed as a credible threat by terrorism experts because of the quantity of an agent needed and the degradation of chemicals that results from standard water disinfection processes. However, a chemical attack on post-purification drinking water storage in a small municipality or a specific building is viewed as more credible, but difficult to get without site-specific knowledge and access. By extension, intentional chemical contamination of passenger drinking water within the transportation system is possible, but probably would not be a very large event in terms of injuries or casualties.

Food contamination with toxic chemicals is also possible. Although only isolated cases of intentional food poisoning have occurred, several single accidental food poisoning events within the last decade have sickened thousands of people, suggesting the potential effects that could be achieved with intentional food poisoning.

Dispersion, and Population Density

The density of the population in the area at risk affects the means for communicating instructions and the choices of transportation-related responses. The number of individuals at risk during a chemical event depends on the population density and the area over which health-threatening levels of contamination are dispersed. Health-threatening levels are determined by the type and toxicity of the chemical and the exposure route. Dispersion is determined from the physical form of the chemical (i.e., gas, liquid, solid, or particles), topology and meteorology (i.e., rain and wind currents), and the quantity released.

One of the more common worst-case scenarios of a chemical incident involves the release of a chemical that is a gas under ambient conditions, but is transported as a liquid under pressure in 90-ton railroad tank cars. A release from one of these cars carrying chlorine or ammonia has been projected to create a danger zone in the range of 14 miles—in a highly urbanized area, such a release could affect millions of people. When pressurized liquids are released, part of the liquid immediately flashes to a gas, forming a vapor cloud. The remainder may be fragmented into fine liquid droplets (i.e., an aerosol), which will soon evaporate. Depending on the release conditions, some of the liquid may form an evaporating liquid pool on the ground. The highly turbulent nature of these releases facilitates mixing with air. Within a minute, the cloud typically consists of air with a few percent of the released chemical. The vapor cloud is heavier than air, causing it to slump to the ground, becoming a broad cloud that backs up against the wind. Within a few minutes, a release of common bulk transport quantities of a liquefied gas (i.e., 20 to 90 tons) can cause a vapor cloud with a backup of several hundred meters and a width of a kilometer or more. Depending on atmospheric conditions, the size of the release, and the toxicity of the released gas, the area of concern may

TABLE 2-5 Individual Particle Size of Commonly Used Substances

Substance	Individual Particle Size (Microns)	Inhalable / Respirable
Beach sand	74 to 187	No
Table salt crystal	100	No
Powdered confectioner's sugar	10	Inhalable
Talc powder	1.5 to 37	Inhalable and Respirable
Tobacco Smoke	0.5	Inhalable and Respirable

soon extend as much as tens of miles downwind before gradually falling below the concentrations of concern. Heavy vapor clouds also tend to run into depressions, ditches, drains, and basements of buildings (if released in an urban area). They can persist there for several hours if the wind speed is low or if enclosed spaces are not well ventilated. This can be dangerous for unwary members of the public and emergency rescue personnel.

Computer models such as RMP*Comp (Risk Management Plan offsite consequence analysis software) (EPA, 2004) are used to predict the area over which a toxic cloud may spread. These models generally are conservative, so the distance over which a cloud would cause harmful effects in the field would often be less than predicted by the models. Atmospheric conditions such as inversions may have a substantial effect on the dispersion of toxic gases. An inversion is considered the optimum condition for an open-air chemical weapons release. Inversion occurs when the ground is cooler than the air, and temperatures increase further from the ground. Under these conditions, there is little air turbulence and wind speeds are low, thereby reducing the rate of dispersion of a chemical release. The 1984 release of methyl isocyanate (a choking agent) at a pesticide factory in Bhopal, India, occurred during an inversion, which had slow but steady winds. The toxic cloud moved to a densely populated area where it killed more than 2,500 people and caused tens of thousands of permanent respiratory injuries.

Similar to gases, aerosols and fine particles from chemical weapons may be dispersed by natural wind and wind generated from traffic. In contrast to gases, particles dispersed by wind eventually will be deposited onto surfaces. The atmospheric dispersion of small particles and aerosols is affected by many factors, such as energy in the dispersion (i.e., fire, heat, or explosion), height of release, presence of obstructions (e.g., buildings, hills, and mountains), and weather conditions (e.g., wind speed and direction, temperature, humidity, rain, and cloud cover). The most important factors are wind speed, wind direction, energy and height of release, and the presence of obstructing structures or natural features. Re-suspension of particles with traffic-generated wind is possible but most of the chemical agents are gases or aerosols for which re-suspension is not generally an issue.

Spilled liquid chemicals will form a slowly evaporating pool on the ground. The rate of evaporation is affected by factors such as the boiling point of the liquid, ambient temperature, the area over which the liquid spreads, and the wind speed. The Aum Shinrikyo cult used an evaporating liquid to release a few liters of the nerve agent, sarin, in commuter trains on three Tokyo subway lines in 1995. The sarin was concealed in lunch bags and soft-drink containers, and placed on subway train floors. The containers were then punctured with umbrellas, spilling sarin on the floor as the perpetrators left the trains (Ohbu et al., 1997). The incident resulted in 12 deaths and about 1,000 injuries. Pouring liquid nerve and blister agents on the ground or floor is a relatively inefficient way of dispersing them. If terrorists were able to obtain or manufacture chemical munitions, they could cause a more devastating effect.

The use of crop duster planes to disperse chemical weapons agents is considered to be possible, but very unlikely. Without substantial reconfiguration, crop-dusters can only release liquid droplets that are much larger than can be taken into the lungs, thus only agents that cause injury by contact could be effective. Blister agents and the nerve agent, VX, have been identified as potentially able to be effectively dispersed with a crop duster. Difficulties would include preventing leakage (for VX in particular, even minimal exposure would kill the pilot before leaving the ground) and infiltrating both a crop duster company and one of the traditionally separate, specialized companies that load chemicals into crop dusters.

2.1.3 Threats and the Transportation System

The transportation system has particular vulnerabilities with respect to chemical threats and, as discussed below, is likely to be involved in actions to minimize the consequences of a chemical event.

Transportation System Vulnerabilities

A chemical release event that occurs near or in any transportation mode can contaminate the roadway or track on which vehicles travel, transportation vehicles, passengers, and cargo passing through the contaminated area. Factors that make a transportation mode more vulnerable to sustained toxic concentrations during a chemical event include the presence of enclosed spaces, the likelihood of persistent contamination, and the ease (or difficulty) of decontamination. These factors and other vulnerability factors are summarized in Table 2-6 for each transportation mode.

Enclosed spaces such as tunnels and, to a lesser extent, road and track surrounded by tall buildings, may more readily retain toxic vapors, aerosols, and particles than open spaces. Gaseous and aerosol chemicals may enter vehicles and vessels with air, and in all transportation vehicles, may be more readily retained in passenger and cargo compartments than in the open air. Factors that reduce the ability for quick dilution of toxic gases or aerosols (e.g., enclosed spaces) allow people and cargo to receive larger doses, thereby increasing health effects. Among the largest public populations at risk in enclosed spaces are in transit underground stations or terminals, airport terminals, large civil aircraft, and passenger cruise ships. Enclosed spaces with HVAC systems have increased exposure risks caused by continued circulation of toxic chemicals in the form of gases, aerosols, or fine particles. Food and water cargo present

TABLE 2-6 Vulnerabilities to Extended Chemical Exposure for Each Transportation Mode (Note: High = more vulnerable (higher risk), Medium = medium vulnerability, Low = less vulnerable (lower risk))

Chemical Vulnerability	Highway	Rail	Transit	Aviation	Maritime
Enclosed space	• Tunnels • Passenger compartments	• Tunnels, • Stations • Passenger compartments	• Tunnels • Stations/terminals • Passenger compartments	• Aircraft • Terminals	• Cruise ships • Terminals
Persistent contamination[a]	High for passenger vehicles	High for stations, passenger trains	High	High for aircraft and airports	High for cruise ships, and terminals
Ease of decontamination[a]	Moderate	Moderate	Moderate	Moderate	Moderate
HVAC spread contamination	None	Within passenger car or station	Within passenger compartments, terminals	Within airports and aircraft	Within cruise ship and terminals
Drinking water contamination	None	Passenger drinking water	Passenger drinking water	Passenger drinking water	Passenger drinking water
Agricultural cargo contamination	Yes	Yes	No	Slight	Yes
Able to contaminate other modes	Transfer points	Transfer points	Transfer points	Airport terminal	Dock

a: Persistent contamination and decontamination are only issues when a persistent chemical is released (i.e., some chemical weapons agents).

concerns as both a primary target for contamination and as transportation system cargo that has passed through a contaminated area.

Toxic particles and, to a lesser extent, aerosols, can be re-suspended or evaporated more quickly by air currents generated by passing traffic. In the contaminated area, highway vehicles and rail or subway cars in particular can expand the contaminated area. Contaminant spread by traffic could also be an issue in ports, docks, canals, and rivers. The open sea, however, is not susceptible to significant chemical contamination from passing ships because its enormous volume would dilute any toxins to an insignificant concentration.

Intersecting modes of transportation can result in cross-contaminating one transportation mode from another. Primary mode intersections include rail crossings, stations, airports, ports and docks, and mass transit lines and/or stations. This physical proximity can result in contamination spreading from one transportation mode to another.

Consequence Minimization of a Chemical Event

The first response in the event of a chemical release that contaminates transportation pathways would be to close the affected paths until a non-persistent chemical is diluted or chemically broken down or until a persistent chemical is otherwise removed. Depending on the released agent's persistence, potentially contaminated people, vehicles, and associated cargo may be routed to isolation and decontamination areas or directly to medical assistance. Transportation would need to be provided for first responders to assist trapped or injured people. For rapid response in the event a chemical weapons agent is detected in association with an explosion, emergency response plans may specify an immediate, conservative radius surrounding the explosion site for evacuation. These boundaries may be adjusted after a more complete chemical survey. A difficult and probably controversial aspect of determining transportation response goals will be in establishing the physical boundaries of isolation areas. Transportation officials are unlikely to have primary responsibility for these decisions and probably will be following instructions from the emergency operations center.

In the event of a persistent chemical release, successfully routing all potentially exposed traffic to decontamination areas depends on the time it takes to recognize that a chemical weapons agent has been released. Symptoms from most chemical agents appear within minutes, but in the case of delayed detection of a release, effort may be needed to identify, decontaminate, and provide medical assistance to contaminated travelers, vehicles, and cargo after they have left the area of initial contamination.

In some outdoor release cases (e.g., blister agent or VX), it may be safer for people to remain inside buildings (i.e., shelter-in-place) than to evacuate. In other cases, such a distant release of a large amount of a choking agent that may travel to a populated area, population evacuations may be necessary. In these cases, transportation paths may be re-routed to expedite one-way travel. If the people, vehicles, and cargo from evacuated areas have the possibility of being contaminated with a persistent chemical, isolation and decontamination stops would be established along evacuation routes. Essentially all modes of transportation may assist in population evacuations, as well as in the transport of first responders and provision of emergency response supplies. Any transportation modes with large buildings may be considered for use as temporary shelters.

2.2 BIOLOGICAL THREATS

Familiarity with the fundamentals of biological agents can be useful in developing appropriate emergency response plans. Depending on the particular biological agent, effects range from sickness to death, and treatment of infections range from administration of vaccines and antibiotics that may prevent or destroy the infection to simple supportive care to keep infected people as comfortable as possible while their bodies fight the infection. This section addresses biological organisms that may pose either a human health threat or an agroterrorism threat and toxins produced by biological organisms. Subsections are fundamentals (2.2.1), emergency response information needs (2.2.2), and biological threats and the transportation system (2.2.3).

2.2.1 Fundamentals

This section provides background information for better understanding of biological threats. The fundamentals addressed below are

- Basics,
- Events,
- Dose and infectivity,
- Categories,
- Detection, and
- Decontamination.

More information on biological threats is available from many commonly available sources, including the Internet.

Basics

There are three general types of biological threat agents: bacteria, viruses, and toxins produced by biological organisms.

- Bacteria are single-celled organisms that have a cell wall, cell membrane, and DNA found throughout the cell, rather than in a compartment (i.e., they do not have a nucleus, as in plant and animal cells). Bacteria reproduce by division and are commonly cultured in broth or on a nutrient gel. When bacteria establish themselves and replicate in the human body they can cause disease. Some bacteria can form spores. Bacterial spores have extremely tough outer coatings that allow them to survive in hostile environments in an inactive state, similar to hibernation. When spores settle in favorable conditions, they become vegetative bacteria, which can grow and reproduce.

  Most bacterial diseases can be effectively treated with antibiotics (i.e., drugs that kill bacteria) if treatment is begun before the onset of symptoms, generally 1 to 4 days after exposure. For anthrax, more treatments may include vaccination and antitoxins, the latter of which counteract the toxin that this bacteria produces while growing in the body.
- Viruses are much smaller than bacteria. Viruses must be inside a host cell to replicate, thus they cannot replicate before infecting an organism. Two frequently used production methods for viral replication are cell culture and inoculation of fertilized chicken eggs.

  Medical treatment of viruses is more difficult than for bacteria. Diseases from some viral agents (i.e., smallpox and certain influenza strains) can be prevented with vaccines. Vaccines are products that produce immunity to specific diseases, preventing the disease from occurring. When vaccines are available, they must be administered before the onset of disease symptoms to be effective. Antiviral agents can destroy or weaken some viruses and also may be helpful for some viral diseases (e.g., smallpox and possibly some hemorrhagic fevers). However, in many cases, the treatment for viral diseases is limited to supportive care.
- Biological toxins are non-living chemicals produced by living organisms, in contrast with the human-manufactured toxins discussed in the chemical threats section. Examples are ricin, from the castor bean plant, botulina from the bacteria *Clostridium botulinum*, and mycotoxins from fungi (i.e., molds). Many biological toxins are relatively stable.

  Diseases from some biological toxins can be treated with antitoxins (i.e., botulism), but these are not available for others (i.e., mycotoxins and ricin). In these cases, treatment is limited to supportive care.

Biological organisms are given a two-part name, where the first name represents the genus and the second name is unique to the species. There can be different versions or strains of the same species. Often, the ability of an organism to infect people easily requires only a different strain. Different strains of the same type of organism also may have different resistance to antibiotics.

A wide variety of biological threat lists circulate throughout the government and medical communities. These lists contain the same disease-causing organisms and toxins of typical concern, with variation in the inclusion of agents thought to be less likely to be used in an attack. Table 2-7 lists some commonly considered bioterrorism agents, the diseases they cause, and their Center for Disease Control (CDC) categories, which are described below in "Categories."

TABLE 2-7 Potential Biological Terrorism Agents

Agent Type	Organism Name	CDC Category	Disease Caused	Host Organism
Bacterial spore	Bacillus anthracis	A	Anthrax	Human/Livestock
	Coxiella burnetii	B	Q-fever	Human/Insects
	Brucellae spp.	B	Brucellosis	Human/Animals
Vegetative bacteria	Yersinia pestis	A	Plague, bubonic and pneumatic	Human/Insects
	Burkholderia mallei	B	Glanders	Human/Livestock
	Francisella tularensis	A	Tularemia	Human/Insect/Animals
Virus	Variola major	A	Smallpox	Human
	Filoviruses and Arenaviruses (Ebola, Marburg, Lassa)	A	Hemorrhagic Fevers	Human/Insects/Animals
	Foot and Mouth Virus	NA	Foot and Mouth Disease	Livestock
Toxin produced by organisms	Clostridium botulinum	A	Botulism	NA*
	Castor bean	B	Ricin	NA*
	Various Funji	A	Mycotoxin toxicity	NA*

NA = not applicable. Biological toxins are produced by organisms, but are chemicals rather than living organisms, hence they do not have a host. All listed toxins are toxic to humans

The potential for exposure is defined as the probability of an individual to be exposed to the agent. Susceptibility refers to the likelihood of an agent to cause disease in a population exposed to the agent.

Persistence of a biological agent relates to how long it remains a danger and how difficult it is to render harmless. As with chemical agents, the persistence of an agent in the environment depends on factors such as temperature, humidity, and sunlight. The persistence of a biological agent may be quite different in the air, versus on surfaces or in soil or water. In this report chemical agents that substantially degrade in open air within 24 hours of release were defined as non-persistent. However for biological agents, the definition of non-persistent is extended to 48 hours because, for the biological agents addressed, persistence in open environments is either 48 hours or less, or a week or more, making a greater distinction between persistence categories delineated by 48 hours. For non-persistent biological agents in particular, survival is often substantially longer in soils than in open air. Vegetative bacteria and viruses typically are not very persistent in an open environment, thus they only present a long-term risk when they are contagious. In contrast, spores are typically very persistent, lasting months to years in an open environment.

Contagiousness refers to the ability of the biological agent to be spread from one person to another after it has increased in numbers in the initially infected person. Highly contagious agents can be spread with face-to-face contact, as coughed or exhaled droplets from infected individuals in a contagious stage of the disease are inhaled by others. Some highly contagious agents may also be transferred to others from touching the skin, clothes, or bedding of an infected individual or corpse. During the most contagious stages of these diseases, infected individuals tend to be obviously sick and often bed-ridden. Less contagious agents may be spread with bodily fluids.

Events

Responses to biological events are driven primarily by the type, quantity, and dispersion of the biological agent. Recognition of the types of possible biological events can help in assessing vulnerabilities and risk. Three general types of biological events are as follows:

- Natural spread of a disease caused by a biological agent not deliberately concentrated as a weapon or for research purposes. SARS, West Nile Virus, Hong Kong Flu, and Avian Bird Flu are recent examples of biological threats that have not been deliberately concentrated. Influenza viruses, which cause the flu, are the biological group generally thought to pose the greatest risk of natural spread caused by their ability to continually mutate into new strains, thereby making established vaccines ineffective. One of the most extreme influenza outbreaks recorded was in 1918.[2] Estimates of deaths worldwide from the 1918 flu outbreak range from 20 million to 100 million. There is an increased potential for the promotion of natural spread of disease during events with other threat agents (i.e., conventional, chemical, or radiological) when responses include crowding of injured or displaced people, which may enable the evolution of new, more contagious strains.[3]

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[2] In the U.S., deaths from the 1918 influenza outbreak were at least 500,000, representing 5 percent of the population at that time.

[3] The crowded conditions of wounded soldiers in WWI are thought to have facilitated the development of the influenza virus that caused the exceptionally deadly 1918 outbreak. It has been suggested that in the previous year, a strain that was not initially very contagious, was more easily spread under extreme crowding of wounded soldiers, in particular, providing more opportunity for strain evolution. Similarly, Southeast Asian markets with dense crowding of a wide variety of animals (i.e., poultry and livestock,) and people are thought have facilitated viral strain developments that have lead to the more recent threats from Avian Flu and SARS.

Lack of knowledge prevents new strains from being used as a weapon in bioterrorism.

- Release during transport of biological material is the accidental or intentional release of harmful biological material being shipped within the transportation system. Such material is considered DOT Class 6 material, "Toxic and Infectious Materials." These materials have strict shipping requirements to minimize leakage and release. Such a release could occur following accidental or deliberate demolition of a carrier through the use of an explosive device.
- Deliberate release of a biological weapon is a release of a biological agent with the intent to harm a target. A small amount of a biological weapon may be sufficient to have significant effects in enclosed places such as buildings, tunnels, or subways, or within passenger compartments of airplane, trains, cruise liners, buses, and so forth. Larger amounts are needed for an effective outdoor release. Areas with high visibility, large crowds, and high economic effect are thought to be the most likely targets for bioterrorism.

The most dangerous form of biological weapons agent is an aerosol, which is not the natural state of these organisms. Much sophistication is required to generate "weaponized" forms of these agents as found in the anthrax mailings in 2001. Materials legally transported within the transportation system are not weaponized agents and thus are less likely to remain suspended in air. However, these materials can still contaminate surfaces, causing access restrictions until appropriately decontamination.

Dose and Infectivity

The infectivity of a biological agent is the actual number of inhaled organisms necessary to generate an infection. These numbers are generally presented as the infectious dose (i.e., number of organisms) required for 50 percent of those individuals exposed to become infected (abbreviated ID_{50}). In contrast, contagiousness refers to how easily an infectious agent can be spread from person to person. Infectivity, or ID_{50}, can be more clearly measured than contagiousness. Therefore, many experts refer to infectivity rather than contagiousness. Agents that cause highly contagious diseases often have low infectivity; however, not all agents with low infectivity are highly contagious. The infectivity and contagiousness of different biological agents are commonly used to define categories of these agents.

Categories

The Centers for Disease Control (CDC) assembled a panel of experts in 1999 to rank potential biological terror agents based on their public health effect, dissemination potential, public perception of the risk, and the need for special preparation to respond adequately to a deliberate attack. The ranking did not include clean-up costs or plant and animal pathogens that do not infect people. The resulting ranks were used to establish three risk categories: A, B and C. Category A agents can cause high mortality rates, can be relatively easily spread either by contagiousness or delivery as a weaponized aerosol, and may have major public health effects. Category B agents are moderately easy to disseminate and result in a moderate rate of disease and low mortality rates. This category includes the major threats to food and water supplies. Category C agents are those that do not currently pose a significant bioterrorism threat but could emerge as future threats.

The CDC categories are often referred to in various references. However, for this report, the primary characteristics of a biological agent that affect the emergency response are the agent's persistence in the environment, which helps determine the need for decontamination, and the agent's contagiousness, which determines the possible need for quarantines. Quarantines are only considered for highly contagious agents. Based on contagiousness and persistence, the following categories of biological agents are referred to in this report and summarized in Table 2-8:

1. High persistence, low contagiousness—These biological agents take weeks to years to degrade naturally in the environment, but they are not typically transmitted from person to person. The causative agent of anthrax, the spores of *Bacillus anthracis* (BA), is the only CDC Category A organism that falls within this group. Depending on the strain, BA may cause death in 85 percent of infected individuals if untreated. For BA, the dose required for infectivity has been estimated to be between 8,000 to 10,000 spores. Lower numbers may be required for cutaneous (open wound, skin infections) or gastrointestinal forms of the disease. After washing to remove spores from skin and removal of contaminated clothing, it is difficult to transfer an infective dose of BA. The causative agent of Q-fever, *Coxiella burnetii*, is also a bacterial spore, and a CDC Category B agent that typically does not cause death. For *Coxiella burnetii*, the dose required for infectivity may be as low as one spore. Bacterial spores of both agents may last months to years in the environment. The causative agents of brucellosis, several bacterial species of the genus *Brucella*, are CDC Category B agents that typically do not cause death. *Brucella* is not able to form spores, but is relatively stable in the environment and can survive up to 6 weeks in dust. *Brucella* is relatively easy to decontaminate, while bacterial spores can be very difficult to decontaminate because of their protective spore coat. Of the toxins in this group, mycotoxins (produced by molds, e.g., T2 or

TABLE 2-8 Biological Threat Groups

CONTAGIOUSNESS	PERSISTENCE *(and CDC categories in parentheses)*	
	LOW = Less than 2 days in an open environment	HIGH = Weeks to years in an open environment
LOW = Unlikely person to person transmission	Bacterial Diseases: Tularemia *(A)* Plague, bubonic *(A)* Glanders *(B)*	Bacterial Diseases: Anthrax *(A)* Q-fever *(B)* Brucellosis *(B)*
	Toxin Diseases: Botulism *(A)*	Toxin Diseases: Mycotoxins *(A)* Ricin *(B)*
HIGH = *** Likely person to person transmission	Bacterial Diseases: Plague, pneumonic *(A)* Viral Diseases: ** Smallpox *(A)* Hemorrhagic fevers *(A)* Influenza *(no CDC category)* Foot-and-mouth* *(no CDC category)*	None known

* Foot-and-mouth is highly contagious among livestock, it does not cause disease in people.

** Persistence may be longer on surfaces, clothing, and bedding.

*** Note: highly contagious agents can remain persistent within the population regardless of persistence in open environments

yellow rain) are very difficult to decontaminate, while ricin (extracted from castor beans) is relatively easy to decontaminate.

2. Low persistence, low contagiousness—Bacteria and toxin in this group cannot survive in the open environment for more than a couple of days. Many of the bacteria in this group last only a few hours in open air, while botulinum toxin may take a couple of days to substantially degrade depending on specific conditions (i.e., it may be stable for weeks in non-moving water or food). Both bacteria and toxins in this group are relatively easy to decontaminate. The bacteria in this group are relatively infectious, generally needing only 10 to 100 organisms to cause an infection, and include both CDC Category A agents (i.e., causative agents of the bubonic plague and tularemia) and Category B agents (i.e., causative agents of glanders[4]). Botulinum toxin is produced by the bacterium *Clostridium botulinum* under special conditions such as in poorly prepared canned goods and fish products. One of the most poisonous substances known to man, it is a CDC Category A agent. As with other diseases caused by toxins, botulism is not contagious. The contagiousness of bacterial diseases in this group is relatively low. The bubonic plague is caused by *Yersinia pestis*. Although this disease is generally not very contagious, the same causative bacteria can also cause the pneumonic plague, which is very contagious and listed in the group below.[5] If untreated, diseases in this group may cause death in 33 percent (i.e., tularemia) to 100 percent (i.e., glanders) of the affected population. As few as a dozen organisms may be sufficient to cause an infection in a person, but these infections can be effectively treated with antibiotics.
3. Low persistence, high contagiousness—The combination of high contagiousness and high lethality makes the agents in this category formally listed as or equivalent to CDC Category A.[6] The causative agent of smallpox, Orthopox virus *Variola major*, is usually transferred from person to person in airborne droplets from the infected person's coughing or breathing. It may also be transferred through skin sores, secretions, and contaminated clothing and bedding. Some of the hemorrhagic fever viruses (e.g., Ebola, Lassa, and Marburg), *Yersinia pestis* in pneumonic plague cases, and influenza viruses may also be readily transferred from person to person. Weaponized versions of smallpox, hemorrhagic fever viruses, or *Yersinia pestis* would likely be formulated for

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[4] The summary references on glanders used in this report provide conflicting information on stability in an open environment. Glanders-causing agent *Burkholderia mallei* is reported to be sensitive to UV light by Acquista (*The Survival Guide: What to do in a Biological, Chemical, or Nuclear Emergency.* 2003, Random House Trade Paperbacks, NY, p. 28), likely causing its rapid degradation outside. However, it is listed as "very stable" in The National Academies Fact Sheet on Biological Attack, available at: http://www.nae.edu/NAE/pubundcom.nsf/weblinks/CGOZ-6C2MCR/$file/Biological%20Attack.pdf.

[5] *Yersinia pestis* can be transmitted through flea bites to infect human lymph nodes, causing the bubonic plague, which is not easily transmitted to another person because the bacteria reside in the lymph nodes rather than in the lungs. In contrast, if the same organism infects the lungs, it causes the pneumonic plague, which can be readily transferred through person-to-person contact with exhaled droplets making it highly contagious. A bioweapon would likely disperse *Yersinia pestis* as an aerosol, allowing inhalation and causing pneumonic plague.

[6] The CDC Categories A, B, and C were developed for bioterror agents that infect people. The influenza viruses pose a natural spread risk rather than a bioterror risk, and as such, have not been formally assigned to a CDC bioterror category. However, based on statistics from the 1918 influenza outbreak, lethality may approach that of smallpox (i.e., 30 percent) when a vaccine is not available, suggesting equivalence to CDC Category A for some influenza strains.

> inhalation. All agents in this group are relatively easy to decontaminate in the open environment. For livestock, the foot-and-mouth disease is caused by a highly contagious virus. Although this disease is not known to be transferred to people, it could cause substantial economic disruption.

At this time, no commonly recognized biological threat agents are both very persistent in an open environment and very contagious. Also, for the purpose of this study we have included Foot and Mouth Virus (FMV) as an agroterrorism threat that is highly contagious but not persistent. Recent events in Taiwan and the United Kingdom have demonstrated the severe negative economic effect of an FMV outbreak among livestock. This virus is highly contagious among livestock and sufficiently stable in the environment to travel many miles through the air to infect other hosts.

Detection and Identification

The terms "detection" and "identification" are frequently interchanged in the context of biological warfare compounds, even though they have very different meanings. Detection of biological agents refers to the ability to discriminate between biological and non-biological material without further characterization. Not all biological materials are hazardous and these technologies do not discriminate between "good" and "bad" biological organisms. Identification is the ability to discriminate between biological materials and accurately name them. The difference between detection and identification is the degree of resolution.

Biological detection technologies detect the presence of airborne biological particles in a sampled volume of air. Changes in the number and types of particles in the air may indicate the presence of a biological hazard. Generally these detection technologies can discriminate bacteria and spores from pollen and fungi also present in the atmosphere. These detectors either use measurement of induced fluorescence, generally from protein components characteristic of a biological organism, or the identification of adenosine triphosphate (ATP) that is indicative of a living biological organism. The fluorescent detection technology is more sensitive than ATP detection, but it cannot discriminate between live and dead organisms. Detectors that discriminate live and dead particles are relatively expensive and do not discriminate between "good" and "bad" organisms, so are subject to false or nuisance alarms. These systems serve as "triggers" to activate an identification system. Detection systems can provide a first level of response in a transportation surveillance system.

Biological identification technologies are used to name the type of biological material detected. The most common approaches to biological identification are antibody-based assays and nucleic acid (i.e., DNA) amplification and identification assays. Each of these technologies has benefits and limitations, but used together can result in sensitive detection with a high degree of confidence.

Some antibody identification methods, such as hand held assays, are relatively simple, single-use devices that require little in the way of maintenance other than proper storage conditions. The sensitivity of antibody-based identification technologies depends on the availability of sensitive and specific antibody reagents. The most well-known type of antibody-based identification in the biodefense market is hand held immuno-chromatographic assays (HHAs), also referred to as antibody "tickets." In general, HHAs are designed for one agent identification per assay. Although the systems are relatively robust, they are not as sensitive as DNA amplification-based identification systems. These systems are commercially available and provide a responder with rapid, onsite analysis of some biological agents.

DNA identification methods use an organism's genetic code for positive identification. These methods require substantial operator training and maintenance requirements. DNA-based anthrax identification systems are in the early stages of operation at select U.S. postal facilities. DNA identification for a wider variety of materials requires more procedural development. Specific biological toxins are identified with mass spectrometry, which requires substantial operator training and maintenance. Use of these technologies for laboratory or confirmatory analysis of samples from the transportation system would likely either be contracted from a commercial firm or be conducted by another government agency.

None of the identification technologies can determine if a biological agent is alive or dead, and a dead bacterium or virus cannot cause infection. A live agent is confirmed by its ability to grow in a culture media; such growth may take several days. The ability to discriminate between live and dead agents is critical for verifying decontamination technologies.

Decontamination

Decontamination is the inactivating or killing of bacteria, viruses, or toxins. Spores represent the most significant inactivation challenge. Vegetative bacteria and viruses are relatively susceptible to many means of remediation. Toxins have varying degrees of resistance, but can be inactivated by many of the materials used for decontamination. Surface decontamination of most biological agents can be achieved using disinfecting solvents, foams, gels, or emulsions. A 0.5 percent hypochlorite solution (i.e., 1 part household bleach, 9 parts water) is a common recommendation. Line-drying clothes in the sun allows ultraviolet rays to kill most organisms. The use of disinfectant foams can increase the time a surface is exposed to effective concentrations of a disinfectant, which increases the likelihood of destroying the biological agent—a particular concern for more persistent agents (e.g., anthrax spores and mycotoxins). Mycotoxins are the most difficult of the biological agents to destroy; however, as toxins rather than viable organisms, they may be washed away and diluted to safe levels with soap and water.

Gaseous decontamination, or fumigation, applies to enclosed spaces. The primary choices for destroying bacteria and viruses are chlorine dioxide, methyl bromide, para formaldehyde, ozone, vapor hydrogen peroxide, and ethylene oxide. Any gas or vapor that can kill bacteria is also harmful to humans. Chlorine dioxide was used in 2001 to remediate anthrax in the Hart Senate Office Building and the Brentwood U.S. Postal Distribution Center. The remaining disinfectant gas was later broken down by the addition of sodium bisulfate. Vapor hydrogen peroxide was successfully used by the Department of State to decontaminate a mail sorting facility in Sterling, Virginia, in 2002. Particularly in the cases of anthrax spores, administering vaccines may sometimes be more practical than complete decontamination.

After decontamination, removal or cleanup of the disinfectant is required. Wide area decontamination would require close coordination with the U.S. EPA. The use of large quantities of liquid chlorine (i.e., bleach), in particular, will be subject to EPA and similar state requirements. These requirements may include containing runoff, measuring water quality, and possibly sustained holding of runoff water with other treatment until acceptable levels of both the initial contaminant and any added decontaminants are reached. The EPA has released an alert relative to environmental liabilities caused by mass decontamination runoff.

2.2.2 Emergency Response Needs

Regardless of the cause of a biological release, from an emergency response perspective, the primary considerations for response management are biological agent type and formulation, quantity and persistence, exposure route, dispersion, and population density in the area at risk. These factors and their interrelationship are further discussed below. Table 2-9 delineates some of the information needed in a biological event to decide the appropriateness of transportation goals for evacuation, isolation and checkpoint establishment, and provision of supplies to the contaminated area.

Agent Type and Formulation

The type of agent, its associated infectivity and contagiousness, and its formulation are key factors in assessing the threat posed to human health. The health risk to an exposed population is also affected by the quantity of the agent released and the likely exposure route (i.e., whether the particle size will permit inhalation into the lungs). Similarly, information on the biological agent type and formulation also determines what is needed to protect emergency response and cleanup personnel adequately. Formulation relates to the physical state of the organism, and in particular, the likelihood of the organism being suspended in air. Weaponized biological agents have been treated such that their physical properties favor aerosol dispersion. This quality makes their re-suspension into the air a greater threat than is posed by the naturally occurring forms of the organisms.

TABLE 2-9 Determination of Biological Event Emergency Response

Biological Event
Information Needed to Determine Appropriate Emergency Response
Estimated ***population exposed*** to levels of concern as determined from: ◆ Affected area information *(see below)* ◆ Population data
Estimated ***affected area*** as determined from: ◆ Quantity and infectivity ◆ Location of release and contagiousness ◆ Wind direction and strength ◆ Topography ◆ Surface sampling
Possible ***exposure pathways*** as determined from: ◆ Agent type ◆ Physical form and formulation

Quantity and Persistence

The quantity of a biological agent released and its dispersal and likely exposure routes determine the area over which people may be infected. The persistence determines the duration of the risk of infection. The quantity of a viral or bacterial agent is increased orders of magnitude in an infected individual, while the quantity of a biological toxin is not increased after release. Biological agents that do not survive long in open environments may still be very persistent overall if they are contagious and can be easily transmitted from person to person.

An upper range estimate of the quantity of the release of a biological agent in transport cannot be easily determined based on the container size. Often infectious material constitutes only a small proportion of contaminated medical wastes. Pure bacterial or viral cultures are shipped in small quantities because the receiving institution generally can culture more of the organism as needed, thereby reducing transportation concerns. In the event of a biological weapons attack, estimating the release quantity and associated area with concentrations of concern is difficult and made more difficult when there is a delay between exposure and recognition of an attack (i.e., observable symptoms).

Exposure Routes

Inhalation is the exposure route of greatest concern, and this is likely to be a primary form of exposure for agents dispersed as aerosols with droplets in the 1- to 5-μm-diameter range. This size range can be achieved by using either a solid or a liquid preparation. Because all the biological threat agents exist as solids, the liquid preparation is actually a slurry of particles in solution. Optimal dispersion occurs when the slurry is atomized such that only a few organisms are present in each liquid droplet. Because of the high surface-area-to-volume ratio of these small particles, the liquid evaporates leaving the aerosolized particles suspended in air. Dry agent can also be released after it is treated to result in a majority of particles within the appropriate size. Bacterial spores are ideally suited for this dry method because their nominal size is within this range and they are inherently stable. Vegetative bacteria, viruses, and toxins are better suited for liquid formulations, but can be prepared as dry agent as well.

Particle size is critical for two factors. First, if the particles are too large, they quickly fall to the ground and are no longer an aerosol threat. Table 2-4 in the chemical subsection highlights sedimentation rates for various-sized particles in stagnant air. The second factor is that the size of a particle affects its ability to cause infection. In general, particles greater than 10 μm in diameter are trapped by nasal hairs and released with exhaled air or sneezing. Particles less than 10 μm in diameter are referred to as "inhalable" because they may pass into the upper portions of the lungs, which contain many branched passageways. These passages (i.e., bronchi and terminal bronchioles) are lined with mucus and cilia. The mucus traps particles, and the cilia gradually push particles up and out of the lungs within about a day. These particles are then swallowed. Stomach acids can destroy many types of biological agents, thus preventing infection. The smallest particles (e.g., less than 2.5 μm in diameter) are referred to as "fine" or "respirable" particles. Fine particles may pass into the deepest portions of the lungs (i.e., respiratory bronchioles, alveolar ducts, and alveolar sacs) and may be removed by macrophages over many days, allowing time for bacteria growth and the development of an infection. Bacteria are typically 1 to 5 μm in diameter, while viruses are generally 0.5 μm or less. To put these sizes in perspective, the particle size of some common substances is shown in Table 2-5 of the chemical subsection.

Biological agents either not released as an aerosol or released as large enough particles to settle on the ground pose greatly reduced inhalation risks. Biological agents generally cannot cause infection by skin absorption unless there are open wounds. A notable exception to the inability of biological agents to pass through uninjured skin is mycotoxins, biological toxins produced by molds. Mycotoxins act quickly, similarly to chemical blister agents. They can be distinguished from blister agents by a lack of odor and by a yellow, red, green, or other color associated with oily droplets.

As discussed in the chemical subsection, effective contamination of the drinking water supply of a city-sized population is not generally viewed as a credible threat by terrorism exports. However, an attack on post-purification drinking water storage in a small municipality or a specific building is viewed as more credible, but difficult to reach without site-specific knowledge and access. Alternatively, disruption of the water disinfection process may lead to unhealthy levels of biological disease agents. Intentional contamination of passenger drinking water within the transportation system is possible, but would probably not be a very large event in terms of injuries or casualties.

Food contamination is also possible. Although only isolated cases of intentional food poisoning have occurred, several single accidental food poisoning events with chemical agents within the last decade have sickened thousands of people, suggesting the effects that could be achieved with intentional food poisoning.

Dispersion and Population Density

The density of the population in the area at risk affects the means for communicating instructions and the choices of transportation-related responses. The number of individuals at risk during a biological event depends on the population density and the area over which health-threatening levels of contamination are dispersed. Health-threatening levels are determined by the type of the agent and the exposure route. Dispersion of the initial release is determined from the physical form of the released agent (i.e., aerosol or particles), topology and meteorology (i.e., rain and wind currents), and the quantity released. For contagious agents, dispersion will also follow the path of infected individuals.

Aerosols and fine particles from a biological release may be dispersed by natural wind and wind generated from traffic. The particles dispersed by wind will eventually be deposited onto surfaces. The atmospheric dispersion of small particles and aerosols is affected by many factors, such as energy in the dispersion (i.e., fire, heat, explosion), height of release, presence of obstructions (e.g., buildings, hills, and mountains), and weather conditions (wind speed and direction, temperature, humidity, rain, and cloud cover). The most important factors are wind speed, wind direction, energy and height of release, and the presence of obstructing structures or natural features.

Weaponized biological agents travel with the wind for many miles before being deposited on the ground. The actual number of infected individuals may be greater in areas of lower contamination because these areas are much larger than high contamination areas. Sampling, within enclosed structures and in strategically determined outdoor locations, is the most effective way to identify the extent of contamination. Both surface and air collections are made in areas of high contamination, but in areas of lower contamination, typically only air collections are made because significant amounts are often not found on distant surfaces.

Secondary releases of an agent can be caused by two distinct mechanisms. The first is by the introduction of wind or an explosion in an area of relatively high contamination resulting in the re-suspension of the particles. The second, and more devastating, is the spread of contagious agent by infected individuals, as may be the case with smallpox, pneumonic plague, and some hemorrhagic fever viruses. These diseases may be spread with exhaled air from infected individuals; however, during the disease stages where this is possible, infected persons are usually largely bedridden at home, in hospitals, or other medical centers. Livestock foot and mouth disease may also have secondary releases caused by contagiousness. Contagious diseases in particular may have a significant effect on transportation, which may be restricted or stopped to isolate either clean or infected regions.

2.2.3 Interrelationships between Biological Threats and Transportation Mode

A biological release event that occurs near or in any transportation mode can contaminate the roadway or track on which vehicles travel, transportation vehicles, passengers, and cargo passing through the contaminated area. Factors that make a transportation mode more vulnerable to a biological release include the presence of enclosed spaces, number of passengers, re-suspension of biological particulates, and ease (or difficulty) of decontamination. These factors and other vulnerability factors are summarized in Table 2-10 for each transportation mode.

The highway (trucking) and rail transportation modes are frequent haulers of toxic and infectious medical materials, while the aviation and maritime modes are less frequent carriers of DOT Class 6 infectious materials, and mass transit is never a carrier of these materials. The release of a biological agent during legal transport would disrupt travel along the specific route; however, the likelihood of widespread release of dangerous material is low. If an airplane crash resulted in release of an infectious agent, it is unlikely that the hazard from this release would provide significantly more threat to the personnel. Standard fire suppression techniques would minimize the chance of aerosolization. Because of the small amounts of dangerous biological agents that are transported and secondary packaging, the chance for release of significant levels of respirable particles is very low.

Deliberate releases of gram to kilogram amounts of a biological agent in enclosed spaces (e.g. buildings, passenger compartments of rail, aircraft, and cruise ships) could contaminate many people and surfaces, both of which can serve as secondary sources of contamination. All classes of biological agents would cause serious interruption of service if released in a passenger compartment of a commercial or public vehicle. In transportation system passenger compartments, the contamination would be carried to subsequent destinations and could result in widespread closure of the system. If the passengers did not detect the initial event it would be many days before authorities traced the source to a particular rail, air, marine, or mass transit route. The suspicion of release occurring within a

TABLE 2-10 Vulnerabilities to Biological Threats for Each Transportation Mode (Note: High = more vulnerable (higher risk), Medium = medium vulnerability, Low = less vulnerable (lower risk))

Biological Vulnerabilities	Highway	Rail	Transit	Aviation	Maritime
Enclosed space	• Tunnels • Passenger compartments	• Tunnels, • Stations • Passenger compartments	• Tunnels • Stations/ terminals • Passenger compartments	• Aircraft • Terminals	• Cruise ships • Terminals
Potential for persistent contamination	Low	High for stations, passenger compartments	High for stations and passenger compartments	High for airports and passenger compartments	High for cruise ships, terminals
Ease of decon-tamination	Moderate	Moderate	Easier	Easier	Moderate
Resuspension of deposited contamination	High	High	High	Medium	Low
HVAC spread contamination	None	Within passenger car or station	Within passenger compartments, terminals	Within airports, aircraft	Cruise ship, passenger terminals
Drinking water contamination	None	Passenger drinking water	Passenger drinking water	Passenger drinking water	Passenger drinking water
Ability to contaminate other modes	Yes	Yes	Yes	Yes, at Airport Terminal	Yes, at Dock only
Agricultural cargo contamination	Yes	Yes	No	No	Yes
Transport pathway contamination	Yes (road)	Yes (track)	Yes (transit route)	Only Airport	Docks, harbor, canals, rivers

passenger transport system (i.e., aviation, mass transit, and ferries) could have a devastating effect on customers riding the system. Substantial delays would occur attempting to locate the source. The most devastating medical effect would result from the release of contagious agents. By the time the infections were discovered, there would be many more foci of infection. The protected environment of enclosed spaces would help preserve biological agents, and decontamination efforts may be applied in these areas regardless of the agent's persistence in order to assure safety and public confidence. More persistent agents would require more extensive and time-consuming decontamination measures.

The confined nature of ships and the sequestration of the personnel can, in some cases, minimize a biological agent's effect as occurred with the Norwalk virus incidents. Then, the incubation period was short enough for individuals to become ill while still confined to the ship. This is in contrast to a biological release in the transit, rail, and aviation modes, where the transit time is almost always less than the time required for observable symptoms, and passengers debarking at subsequent stops can serve as secondary sources of contamination. Cargo transport of agricultural products and livestock are another potential target for bioterrorism. Release of a highly contagious virus such as the foot and mouth virus could spread the contamination widely with devastating economic effects. If a transportation mode is contaminated from either an enclosed release or an outdoor release, intersecting modes of transportation can cross-contaminate each other.

A large outdoor release may result in closing transportation paths in the vicinity and downwind of the release site until the limits of dispersion are established. In such an event, vehicle and building windows and HVAC systems should be closed so as to prevent exchanging air with the outside. The duration of risks associated with aerosols may be extended in areas with traffic-induced winds that can re-suspend particles into the atmosphere.

All biological agents would have similar effect during the early phase after a release, however, the duration of the hazard varies with the agent's persistence. Decontamination of viruses and vegetative bacteria may occur rapidly (i.e., hours to days) in the environment in the absence of secondary stabilization additives. Stabilizing agents can extend the life of these agents several-fold. The stability of different biological toxins varies from days to years in the environment. In contrast, bacterial spores (i.e., BA) are stable for years in the outside environment. In their natural form, these agents are quite stable and long-lived in the environment. The formulation as a weaponized agent requires total decontamination because of the ability of these preparations to re-suspend into the air and pose a health hazard.

In all cases of biological agent release, timely detection and identification of the threat is important for developing the most appropriate and effective response. Unlike chemical agents that react within seconds to hours, the delay between exposures to biological agents to onset of symptoms is often several days. This is also confounded by the fact that many of these diseases initially present with flu-like symptoms, which can add days to the correct diagnosis. Furthermore, the later detection and identification occur, the greater the sampling and analysis needed to find out the extent of the contamination. Labile agents such as viruses and vegetative bacteria may escape detection because of their instability in the environment.

2.2.4 Consequence Minimization

A primary factor in minimizing the consequences of a biological release is the delay between the actual event and the discovery that a biological release has occurred. For all biological agents, the sooner a release has been determined, the fewer the number of casualties. Although this differential varies widely between categories, it still is a factor. Once an event has been identified, it must be characterized so that protective and restoration actions can be initiated. Characterization includes identifying the agent and the establishment of the contaminated area. Organisms with low persistence may no longer be detectable in the environment by the time a release has been determined, while stable spores in weaponized formulations will pose a continued health hazard as they are re-suspended by air currents. The size and variable environments in the transportation system present both strengths and vulnerabilities in terms of defense against biological attacks.

If a biological agent is released in an enclosed space (i.e., building or passenger compartment), the HVAC systems may be closed or redirected to prevent continued re-circulation of particles. This action would be the same for chemical and radiological threats, thus an agent need not be identified to initiate this response. If a release occurs outside, building HVAC systems may be set to have slightly positive pressure inside, thus reducing the ability for outside contaminants to enter the building. Once again, this action would be the same for chemical and radiological threats, so an agent need not be identified to initiate this response. The incorporation of HEPA filtration within enclosed transportation facilities will greatly enhance the rapid removal of the threat from the environment.

For rapid response in the event a threat agent is suspected in association with an explosion, emergency response plans may specify an immediate, conservative radius surrounding the explosion site for isolation until the agent is identified and the most appropriate response can be determined. These boundaries may be adjusted after a more complete biological survey with surface sampling and identification of the released agent. A difficult and probably controversial aspect of determining transportation response goals will be in establishing the physical boundaries of isolation areas. Transportation officials are unlikely to have primary responsibility for these decisions and probably will be following instructions from incident command and the emergency operations center (e.g., the state emergency management office or agency). A confounding variable is that there are no rapid identification methods for biological agents, as there are for radiological and chemical agents.

The ability to successfully route all potentially exposed traffic to decontamination areas clearly depends on the time it takes to recognize that the agent has been released. In the case of delayed detection of a release, effort may be needed to identify, decontaminate, and provide medical assistance to contaminated travelers, vehicles, and cargo after they have left the area of initial contamination.

In some outdoor release cases, it may be safer for people to remain inside buildings (i.e., shelter-in-place) than to evacuate. If evacuation of an area is determined to be needed, evacuees would be directed to decontamination areas. In these cases, transportation paths may be re-routed to expedite one-way travel. Essentially all modes of transportation may assist in population evacuations, as well as in transporting first responders and providing emergency response supplies. Furthermore, any transportation modes with large buildings may be considered for use as temporary shelters.

If the released agent or a disease outbreak is contagious, isolation of those infected is essential for containment. In this case, potentially infected people would be directed to area hospitals. Special routes may be designated for transport of potentially infected people. If hospitals cannot handle all those infected, quarters for quarantines may be necessary. In a worst-case scenario, people may be asked to stay isolated from others in their homes. In this extreme scenario, transportation would essentially be reserved for first responders and providing supplies.

2.3 RADIOLOGICAL THREATS

Familiarity with the basic types of radiation that may pose threats can help in developing appropriate emergency response plans. The effects of radiation releases range from increased long-term cancer risks to acute radiation sickness and death. This section presents radiation fundamentals (2.3.1), emergency response information needs for decision-makers (2.3.2), and radiological threats and the transportation system (2.3.3).

2.3.1 Radiation Fundamentals

A general understanding of radiation, including the terms used when referring to radiological threats, can improve communication when dealing with a radiological event. More information on radiation is available from many commonly available sources, including the Internet. The radiation fundamentals addressed are

- Basics,
- Events,
- Categories,
- Doses,
- Detection, and
- Decontamination.

Basics

Radioactivity is a property of unstable atoms. As unstable atoms decay, they release or radiate energy in the form of particles or waves known as radiation. Radiation emanates in all directions from a radioactive material and can bounce off or reflect from surfaces or the air to get around a corner. The energy of the radiation determines whether or not it will penetrate a particular surface. Everyone is exposed to low levels of naturally occurring radiation. We are also exposed to radiation during certain medical procedures such as x-rays.

Ultimately, radioactive atoms decay to a stable atom that is no longer radioactive. The time for half of a specific radioactive material to decay to this stable and non-radioactive form is called its half-life. Half-lives can vary from fractions of a second to billions of years. After a period of ten half-lives, over 99.9 percent of a radioactive material has decayed to a non-radioactive stable substance. Therefore, radioactive materials with half-lives of up to hours decay too quickly to pose significant long-term hazards to humans. Radioactive atoms have the identical physical and chemical properties as their non-radioactive or stable counterparts. Thus, radioactive iron looks, feels, and behaves the same as normal stable iron.

Events

Responses to radiological events are driven primarily by the quantity, quality, and dispersion of the radiological release. However, recognition of the types of possible radiological events can help in assessing vulnerabilities and risk. Four general types of radiological events are described below:

- Radiological Infrastructure Event. Radioactive material may be released from any of the thousands of facilities in the United States that produce, handle, and store radioactive materials (e.g., nuclear reactors, medical centers, factories, food irradiators, research laboratories, construction sites, military depots, uranium mines, nuclear fuel fabricating facilities, and nuclear waste storage sites), or from radioactive materials in transport between these facilities. Two particular types of release events that have received substantial attention and response planning in nuclear threat studies are
  – Nuclear Reactor Incident. This involves the release of dangerous levels of radiation from a nuclear reactor. In an extreme event, such as occurred in Chernobyl,

hundreds of square miles and the health of millions of people may be threatened. In such an event, state agencies would work in tandem with the federal agency that regulates the reactor or the federal agency that owns and operates the reactor to coordinate emergency response. The Nuclear Regulatory Commission regulates civilian nuclear reactors. The DOE and DOD regulate the reactors they own and operate for research and nuclear weapons production. The licensing of nuclear reactors requires establishment of evacuation plans coordinated with the appropriate state and local response agencies.
    - Radioactive Material Transportation Incident. This refers to an accidental or deliberate release of radioactive material in transport. Large quantities of radioactive material are transported in special packages (i.e., casks or containers) which, if breached, can result in significant radioactive release. DOE-licensed haulers for radioactive materials follow pre-approved routes and must have an acceptable emergency response plan for radioactive leaks that includes training and communication with the appropriate state and local response agencies along the shipping route. The effect of such an event could be a radiological dispersal that resembles an inefficient dirty bomb, contaminating the nearby area, including the transportation infrastructure and population.
- Passive Radiological Dispersion. Radiation can be spread passively, without the need of active dispersal mechanisms. For example radioactive material can be placed as pellets or liquid spilled in elevators, trains, or other spaces. Depending on the type of radioactive material and the time of exposure, the health effects experienced by exposed people can be severe, but the number of people and area affected would likely be relatively small.
- Radiological Dispersal Device (RDD). This refers to the use of a forceful (or active) method of spreading radiation into the environment. A dirty bomb (frequently mentioned in the media) is a prime example of an RDD. A dirty bomb uses a conventional explosive, such as dynamite, to scatter a radioactive material, such as spent nuclear reactor fuel rods, or radioactive material from industrial or hospital equipment (e.g., Cesium-137 or Cobalt-60). The potential spread of radiation from an RDD is far less than from a nuclear bomb (referred to as a nuclear yield incident, below), which produces radiation from a nuclear reaction. Analyses of many RDD scenarios suggest that this type of event would probably have minimal prompt fatalities and little serious life-threatening radiation doses to the public. However, all analyzed scenarios have resulted in widespread, low-level contamination causing panic, terror, and significant economic impacts. More details and examples of RDD events are presented in Appendix A-4.
- Nuclear Yield Incident. This refers to the detonation of a nuclear weapon (i.e., atomic, hydrogen, or neutron bomb). These detonations both produce and spread radiation and radioactive fallout (i.e., particles that descend through the air) as the result of either splitting atoms (fission) or fusing the nuclei of two atoms (fusion).[7] The magnitude of such an event would result in substantial federal (civil and military) agency response that would likely exert sizable control on all emergency responses. Although state and local transportation officials would be involved in such a response, specific classified procedures have been developed to guide responders. Thus, this extreme event is not specifically considered in this document.

Categories

Radiation refers to any form of energy that travels through space, such as light, heat, sound, and ionizing radiation. Ionizing radiation is any type of radiation that can cause the particles it strikes to become chemically charged (i.e., ionized). The radiation of concern in WMD is ionizing radiation, and throughout this report, all references to radiation are more specifically referring to ionizing radiation.

Ionizing radiation is produced by atoms that are unstable because they have extra energy or mass. Unstable atoms, also referred to as radioactive materials, give off, or emit their extra energy or mass to become more stable. The energy or mass that is emitted from radioactive materials can be categorized as alpha particles, beta particles, gamma rays and x-rays, and neutrons. These different types of radiation have different properties and therefore pose different hazards. Alpha particles are relatively heavy, cannot travel far, and cannot penetrate the skin, but these particles can cause damage if inhaled or ingested. Beta particles are lighter, can travel farther, and can penetrate the skin. Skin can receive a thermal burn (or beta burn) if it is exposed to a large enough quantity of beta particles. Gamma rays and x-rays are electromagnetic energy that can penetrate farther than beta particles—for example, up to 3 inches of lead. Gamma rays have a shorter wavelength than x-rays and thus have higher, more damaging energy. Gamma rays are only generated in nuclear processes, while x-rays can be generated by either nuclear processes or electronic devices. Neutrons are the highest energy form of radiation and penetrate the farthest. Neutrons are only released during a nuclear detonation or as part of a nuclear reactor leak. Many radioactive materials emit more than one type of radiation simultaneously. For example, the materials considered most likely to be used in a dirty bomb, Cesium-137 and Cobalt-60, both emit beta particles and gamma rays.

Radiation that penetrates body tissues is referred to as external direct exposure. For each type of radiation, the

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[7] In addition to nuclear (ionizing) radiation, these reactions also release thermal radiation, and they are unique in their release of an immediate electromagnetic pulse, or surge of electrical power.

TABLE 2-11 Radiation Shielding, Range, and Exposure Pathways

Property or Hazard	Alpha (α) Radiation	Beta (β) Radiation	Gamma (γ) and X-ray Radiation	Neutron Radiation
Shielding Protection	Normal human skin layer	Less than 1/4 inch of metal, glass, or concrete	2 to 12 inches of lead, or 3 to 18 inches of iron/steel, or 1 to 6 feet of concrete	2 to 6 feet of water, or 4 to 8 feet of concrete
Expected Range of Unshielded Radiation	1 to 4 inches in air	1 to 18 feet in air	Hundreds to thousands of feet in air	Hundreds to thousands of feet in air
External Exposure Pathway to Humans	Open wound absorption	Open wound absorption, and external direct	Open wound adsorption, and external direct	Open wound adsorption, and external direct
Internal Exposure Pathway to Humans	Inhalation and ingestion	Inhalation and ingestion	Inhalation and ingestion	Inhalation and ingestion

protective shielding, expected range of unshielded radiation, and damaging exposure pathways for human health are presented in Table 2-11.

A specific radioactive material, also called a radioisotope, is identified by its element abbreviation and atomic weight. The atomic weight is written either before or after the element abbreviation. For example, radioactive cobalt is identified as ^{60}Co, Co-60, Cobalt-60, or Co^{60}. Radioisotopes can exist as a single pure element or as a compound with other non-radioactive elements. For example, radioactive sodium combined with non-radioactive chlorine can produce radioactive table salt. Depending on the specific element or compound, radioisotopes can exist as a solid, liquid, or gas at normal temperatures.

Each radioisotope has a unique half-life and energy of emission of one or more types of radiation. Energy of emission is measured in electron volts (ev). A higher energy emission results in greater penetration capability through shielding and the human body. In contrast, the quantity of a radioactive material is a measure of how many atoms decay in each second. This is called the activity and is expressed in units of Curies (Ci) or Bequerels (Bq) with 37 billion Bq = 1 Ci.

Doses

Radiation dose to humans is measured in units that quantify the damage that can be done because of the radiation type, energy, and quantity a person has been exposed to. These units are called rem or Sieverts (= 100 rem). Each of these units may be prefaced with milli- (m) or micro (μ), meaning one-thousandth and one-millionth, respectively. The average individual receives background levels of radiation at a rate of about 0.3 rem per year. Background radiation is naturally occurring radiation (alpha, beta, and gamma) from radioactive materials in the soil, air, and water. There is no natural neutron radiation. Lifestyle choices such as living at higher altitudes, frequent air travel, or residing in an area with high natural radioactivity in the soil and rocks can increase the natural radiation received by an individual. The average annual radiation dose in the United States is around 0.5 rem. This is slightly higher than background levels caused by exposure to man-made sources, including medical x-rays, CAT-scans, nuclear medicine, and so forth.[8] Substantial human health effects of radiation occur if the dose received exceeds 100 rem in a period of hours to weeks. A short-term dose to the whole body that exceeds 300 rem could be fatal to some people, depending on medical care. Greater detail on human health effects, established public dose limits, personal protection, and treatment after exposure is presented in Appendix C.

Detection

No type of radiation can be seen, felt, heard, smelled, or tasted. Radiation can only be detected with appropriate instruments. Since September 11, 2001, the design and availability of radiation measurement instruments, called dosimeters, survey meters, detection meters, radiation meters, and Geiger counters, has grown. One instrument can measure alpha, beta, and gamma radiation, but the direct measurement of neutron radiation requires either another instrument or another probe to connect to an instrument. Almost all instruments are portable and battery operated and can be as small as a personal pager or as large as a loaf of bread. For the purpose of first-responder detection of significant radiation, a detector or meter that measures alpha, beta, and gamma radiation dose rates from about 0.1 or 1 mrem/hour to 100 or 1000 rem/hour is adequate and can be purchased for about $400 to $1,500. Field personnel who may be first at the scene of an event may be able to provide critical threat information if they have the appropriate detection equipment.

Decontamination

Almost all radiological events require some degree of decontamination. Removal or decontamination of surface

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[8] National Research Council, 2005. Health Risks From Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2 Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. National Academies Press, Washington, D.C.

contamination is typically achieved with vacuum cleaners or high-pressure water washing with suitable cleaners or detergents. Personnel working in decontamination areas would require proper protective gear, and waste from these areas would be disposed of as radioactive waste. Typically, the ease of decontamination is inversely related to surface adsorptivity. Thus, smooth surfaces, such as new cars and the outside of aircraft, are more easily decontaminated than rough surfaces, such as asphalt, concrete, terminals, stations, vehicle interiors, and so forth.

In the more limited range of a pressure wave from a conventional explosion, radioactive particles may actually penetrate surfaces, rather than just lie on or adhere to the surface. In these cases, the top surface layers of road, tunnel, or walls nearby the blast area may need to be removed and disposed of as radioactive waste. There is no generally accepted guide on the most appropriate methods for dealing with long-term radioactive contamination of large surfaces that are difficult to decontaminate (i.e., asphalt and concrete). Handling of these cases is likely to be controversial and may vary depending on the location, expected surrounding population, and size of the contaminated area.

In marine scenarios, pumped seawater could be effective in removing contamination from ships, docks, and other modes of transportation present in the harbor. If a radiological release is small enough and does not adhere to surfaces, it may be acceptably cleaned within a week; however, decontamination of surface radioactivity generally can be expected to take anywhere from weeks to years, depending on its magnitude and tenacity.

2.3.2 Emergency Response Information Needs

Regardless of the cause of a radioactive release, from an emergency response perspective, the primary considerations for response management are: radiation type and energy, quantity and persistence, exposure route, and dispersion and population density in the area at risk. Table 2-12 delineates the information needed to decide transportation goals for isolation, shelter-in-place, evacuation, and checkpoint establishment in a radiological event. These factors and their interrelationship are further discussed below.

Type and Energy

The type and energy of a radioactive material, and its quantity, determine the extent of shielding or distance needed to protect people from radiation. The type and energy of the radiation also determine what exposure routes are most likely to cause human health effects. For example, low-energy alpha radiation cannot penetrate the skin, but can be damaging if it is ingested or inhaled. In contrast, beta and gamma radiation can pass through the skin (i.e., external direct exposure), and be inhaled or ingested.

TABLE 2-12 Determination of Radiological Event Emergency Response

Radiological Event
Information Needed to Determine Appropriate Emergency Response
Estimated ***population exposed*** to levels of concern as determined from: ◆ Affected area information *(see below)* ◆ Population data
Estimated ***affected area*** as determined from: ◆ Exposure pathway information *(see below)* ◆ Amount of material ◆ Location of release ◆ Wind direction and strength ◆ Topography
Possible ***exposure pathways*** as determined from: ◆ Radiation type ◆ Physical form (gas, liquid, solid) ◆ Specific radioisotope

Quantity and Persistence

The quantity of radioactive material released, in conjunction with radiation type and specific radioisotopes, determines the persistence as a health threat. Gaseous and liquid forms may be diluted to background levels. Releases of types of radioactivity with a short half-life may be isolated and contained until it has decayed to safe levels. Radioactivity with a very short half-life is not among the common threat scenarios. Of the more commonly discussed RDD components, Co-60 may have the shortest half-life (5.27 years). Thus, isolation of areas with Co-60 contamination for a decade would reduce radiation levels to about a quarter of the initial levels. In any case, the feasibility and cost of decontamination would be a significant consideration along with the value of the contaminated area.

Exposure Route

The expected exposure route needs to be assessed for appropriate risk management. As stated above, radiation type and energy determine the likely exposure routes, in conjunction with the physical form of the radioactive material as a gas, liquid, or solid. Inhalation is the primary exposure route of concern for a gas that contains radioactive materials (i.e., unstable atoms that release radiation). Depending on the type and energy of a radioactive gas, exposure through the skin may also be possible. A radioactive liquid would pose the greatest threat when introduced into a potable water system or other drinks, thereby allowing ingestion. As with gaseous radiation, depending on the type and energy of radioactivity in a liquid, radiation may pass from the liquid through the skin.

Solid radioisotopes, in the form of sizeable shapes such as pellets, rods, discs, blocks, and plates, present a human health hazard if they are approached without proper shielding. Exposure may be by skin absorption for beta particles and gamma rays, the latter of which may also be inhaled. Although a large solid mass of radiation is the easiest form to contain, if the solid mass is broken into fine particles, it becomes much more dangerous.

Fine particles of radioactive materials are considered the most likely form in the event of an RDD because the explosion would physically spread particles regardless of whether the radioactive material was initially fine particles or a large chunk pulverized by the explosion. Particles small enough to be inhaled present the greatest concern because they can affect human health though all exposure routes: inhalation, ingestion, and external direct exposure (i.e., radiation absorbed through the skin).

The smaller the particle, the farther it may travel within the respiratory tract. In general, particles greater than 10 μm in diameter are trapped by nasal hairs and released with exhaled air or sneezing. Particles less than 10 μm in diameter are referred to as "inhalable" because they may pass into the upper portions of the lungs, which contain many branched passageways. These passages (bronchi and terminal bronchioles) are lined with mucus and cilia. The mucus traps particles, and the cilia gradually push them up and out of the lungs in about a day. These particles are then swallowed and enter the digestive system. The smallest particles (e.g., less than 2.5 μm in diameter) are referred to as "fine" or "respirable" particles. Fine particles may pass into the deepest portions of the lungs (i.e., respiratory bronchioles, alveolar ducts, and alveolar sacs), where they are removed by macrophages over many days and months, allowing longer-term lung exposure to the radioactive particle.

The smallest particle size that can be distinguished by the unaided human eye is about 30 μm in diameter. Table 2-5, in the preceding chemical agent subsection, shows the particle sizes of some commonly used substances to help put particle size in perspective.

Dispersion and Population Density

The density of the population in the area at risk affects the means for communicating instructions and the choices of transportation-related responses. The number of individuals at risk during a radiological event depends on the population density and the area over which health-threatening levels of radiation are dispersed. Health-threatening levels are determined by the type and energy of the radiation. Dispersion is determined from the form (i.e., gas, liquid, solid, or particles), topology and meteorology (i.e., rain and wind currents), and the quantity of radioactive material.

A radioactive liquid could spill on the ground, puddle, and be absorbed into soil or other solids as well as run into sewers or nearby natural bodies of water. Public exposure to a liquid release could be relatively easily limited, and cleanup would be easier than for fine particles. Overall, topography, obstructions, and plumbing would largely decide the dispersion of a released radioactive liquid. Water disinfection processes cannot reduce radiation levels. Dilution to safe levels is a possible solution for liquid radioactivity in some scenarios.

Open-air gaseous radioisotope releases are generally quickly dispersed and diluted with the surrounding air, thereby presenting a relatively short-term, local radiological hazard. A release of a radioactive gas that is heavier than air may linger longer than expected when there is little wind. Structures such as buildings may also slow the mixing and dilution of released gases with air. Generally, a radioactive gas release in an enclosed space with little or no ventilation poses a much greater threat than a release outside. Predicted dispersion of a gaseous release in conjunction with an estimated radioisotope quantity can together indicate the extent of the area at risk, but many gaseous releases may be essentially completely dispersed by the time this information is considered.

Similar to gases, fine radioactive particles may be dispersed by natural wind and wind generated from traffic. In contrast to gases, particles dispersed by wind will eventually be deposited on surfaces where they may either stick or be re-suspended in the air. There has been extensive study of the atmospheric dispersion of radioactive gases and small radioactive particles (also called particulates). Although many factors affect dispersion of gases and fine particles, the most important factors are wind speed, wind direction, energy and height of release (i.e., fire, explosion), and the presence of obstructing structures or natural features (e.g., buildings, hills, and mountains). Table 2-4 in the preceding chemical subsection provides estimates on how long it takes various particle sizes to settle to the ground in the absence of air currents.

2.3.3 Radiological Threats and the Transportation System

The transportation systems has particular vulnerabilities with respect to radiological threats, and as discussed below, is likely to be substantially involved in actions to minimize the consequences of a radiological event.

Transportation System Vulnerabilities

A radiation release event that occurs near or in any transportation mode can contaminate the roadway or track on which vehicles travel, transportation vehicles, passengers, and cargo passing through the contaminated area. Factors that make a transportation mode more vulnerable to sustained radiation during a radiological event include the presence of enclosed spaces, surface contamination and re-suspension of radioactive particulates, and ease (or difficulty) of decontamination. These factors and other vulnerability factors are summarized in Table 2-13 for each transportation mode.

Enclosed spaces such as tunnels and, to a lesser extent, road and track surrounded by tall buildings may more readily retain concentrated radioactive material than open spaces. Gaseous and particulate radiation may enter vehicles and vessels with air and, in all transportation vehicles, may be more readily retained in passenger and cargo compartments than in the open air. Factors that reduce the ability for quick dilution of radioactive gases or particles (i.e., enclosed spaces) allow people and cargo to receive larger doses, thereby increasing health effects.

Among the largest public populations at risk in an enclosed space are those in transit underground stations or terminals, airport terminals, and large passenger compartments (e.g., trains, cruise ships, and aircraft). HVAC systems in enclosed spaces may increase exposure risks caused by continued circulation of radioactive gases or fine particles. Contamination of food and water cargo present unique concerns both as a specific target for contamination and as cargo present in the transportation modes passing through a contaminated area.

Surfaces with a greater adsorptivity for particles will have greater levels of surface contamination from radioactive particles. Thus, the surfaces are more vulnerable to greater and extended radiation exposure. In general, surface adsorptivity is less at high speeds and for aerodynamic, smooth surfaces including aluminum, steel, and glass (e.g., aircraft and high speed passenger trains). Rough or corroded metal has high adsorptivity, as does bare concrete, asphalt, and fabric. Thus, surface contamination will generally be high for older vehicles, stations, terminals, roads, and clothing.

The ease of decontamination is typically inversely related to surface adsorptivity. Thus, smooth surfaces, such as new cars and the outside of aircraft, are more easily decontaminated than rough surfaces, such as asphalt, concrete, terminals, stations, and vehicle interiors. Time required for decontamination may range from hours to years, depending on the magnitude and tenacity of the radiation.

Deposited solid radioactive particles can be re-suspended by air currents generated by passing traffic. This is a particular concern for highway, rail, and mass transit because traffic on these modes would essentially expand the contaminated area. Spread of the contaminated area by traffic could also be an issue in ports, docks, canals, and rivers. The open sea, however, is not susceptible to significant radioactive particle contamination from passing ships because its enormous volume would dilute any radioactive material to an insignificant concentration. Similarly, re-suspension of radioactive particles by aircraft in flight is a reduced concern because the re-suspended particles would be greatly diluted in the upper air before settling to the ground.

Intersecting modes of transportation can represent a substantial vulnerability because they can allow cross-contamination from one transportation mode to another (e.g., rail crossings, rail and bus stations, airports, ports

TABLE 2-13 Vulnerabilities to Extended Radiation Exposure for Each Transportation Mode. (Note: High = more vulnerable (higher risk), Low = less vulnerable (lower risk))

Radiological Vulnerability	Highway	Rail	Transit	Aviation	Maritime
Enclosed space	◆ Tunnels ◆ Passenger compartments	◆ Tunnels ◆ Stations ◆ Passenger compartments	◆ Tunnels ◆ Stations/ terminals ◆ Passenger compartments	◆ Aircraft ◆ Terminals	◆ Terminals ◆ Passenger compartments
Vehicle surface contamination	High	◆ Low for high speed ◆ High for all others	High	◆ Low for aircraft ◆ High for airports	High
Ease of decontamination	Moderate	◆ Easier for high speed ◆ Moderate for others	Easier	◆ Difficult for aircraft ◆ Easier for airports	Moderate
Resuspension of deposited solid particle contamination	High	◆ High for low speed ◆ Low for high speed	High	◆ Very Low for aircraft ◆ High for airports	◆ Very Low at sea ◆ High in port
HVAC spread contamination	None	Within passenger car	Passenger compartments	High in airport or aircraft	High in cruise ship
Drinking water contamination	None	Passenger drinking water	Passenger drinking water	Passenger drinking water	Passenger drinking water
Ability to contaminate other modes	Yes	Yes	Yes	Yes, at airport Terminal	Yes, at dock
Agricultural cargo contamination	Yes	Yes	No	Slight	Yes
Transport path contamination	Road	Track	Road, track, waterway	Airport	Harbors, canals, rivers

and docks), increasing contaminant spread and area requiring decontamination.

Transportation Consequence Minimization

The first response in the event of a radiation release that contaminates transportation pathways would be to close the affected paths until they can be decontaminated and route contaminated people, vehicles, and associated cargo to isolation and decontamination areas. For rapid response in the event radiation is detected in association with an explosion, emergency response plans may specify an immediate, conservative radius surrounding the explosion site for evacuation. These boundaries may be adjusted after conducting a more complete radiological survey. A difficult and probably controversial aspect of determining transportation response goals will be in establishing the physical boundaries of isolation areas. Transportation officials are unlikely to have primary responsibility for these decisions and probably will be following instruction from the emergency command center (e.g., their state emergency management office or agency).

Roads, in particular, are highly susceptible to radioactive contamination from vehicles that have traveled through an area contaminated with radioactive particles, thus the greater the potential travel time before traffic re-routing, the greater the area of contaminated roadway. Successfully routing all potentially exposed traffic to decontamination areas depends on the time it takes to recognize that radiation has been released. In the case of delayed detection of a radiation release of particles that may adhere to passing vehicles and vessels, effort may be needed to identify and decontaminate potentially contaminated travelers, vehicles, and cargo after they have left the area of initial contamination.

If radiation contamination issues are realized several hours to days after a radiological release, identifying cars and vessels that have passed through a contaminated area would be relatively easy within the rail and aviation system, for which essentially all trips are scheduled by a relatively few organizations. Port logs could identify large vessels that may have passed through a contaminated area. In contrast, the highway system has essentially no means for identifying vehicles that may have passed through a contaminated area, with the exception of trucking industry logs. Mass media requests for highway travelers who may have been passed through contaminated areas to identify themselves may be the only way to identify highway system travelers.

Responses to a radiological event may also involve population evacuations, in which case transportation paths may be re-routed to expedite one-way travel. If the people, vehicles, and cargo from evacuated areas may be contaminated, isolation and decontamination stops would be established along evacuation routes. Essentially all modes of transportation may assist in population evacuations, as well as in transporting first responders and providing emergency response supplies. Any transportation modes with large buildings may be considered for use as temporary shelters. In some cases, it may be safer to have members of the public stay in a protected structure, called shelter-in-place, to avoid exposure to a passing cloud or plume of radioactive material.

2.4 COMPARISON OF CBR THREATS

How much CBR agents affect the transportation system depends on factors such as the specific agent, the amount released, the means of dispersal, and the surrounding infrastructure and population density. In terms of the potential area affected by a single event:

- Chemical releases could quickly affect tens of square miles. While decontamination of the most persistent of these agents may take many weeks, other agents may naturally degrade or disperse within hours.
- Biological releases could also affect tens of miles, and if a contagious agent is used, could soon lead to global effects. While decontamination of the most persistent of these agents may take many weeks, other agents may naturally degrade or disperse within hours.
- Radiological releases such as from a nuclear bomb or major nuclear power plant accident could affect hundreds of miles. However, more likely scenarios involve dirty bombs, which could affect up to about a square mile. Decontamination of persistent radioactivity would probably take months to years.

The amount of a CBR agent needed to inflict a similar level of effect per area varies by many orders of magnitude. Table 2-14 compares the estimated minimum amount of a threat agent needed to cause heavy casualties within a square-mile under ideal conditions (i.e., efficient dispersal and optimal meteorological conditions).

In addition to the amount of an agent needed to cause harm, other important factors in the use of a given CBR agent from the terrorist perspective are ease of acquisition

TABLE 2-14 Estimated Amount of CBR Agents for Heavy Casualties Within a Square-Mile under Ideal Conditions

Agent Category	Description of Material	Grams
Conventional	Fuel-air explosives	320 million
	Fragmentation cluster bombs	32 million
Chemical	Hydrocyanic acid	32 million
	Mustard gas	3.2 million
	GB nerve gas (sarin)	800,000
Radiological	"Crude" nuclear weapon (in terms of fissionable material only)	5,000
Biological	Type A botulinum toxin	80
	Anthrax spores	8

(Source: Kupperman and Trent, 1979)

TABLE 2-15 Comparison of CBR Threats (Short-term = a few hours to a few days; Medium-term = several days to several weeks; Long-term = several months to years)

Event Type	Health Effects		Agent Identification			Decontamination Requirements	Potential Effect on Transportation	
	Overt Event	Covert Event	How Recognized	Field Sensors	Time for Detection/ Identification		Overt Event	Covert Event
Radiological								
High Persistence	Immediate for high doses, delayed for low doses. Treatment can reduce health effects.	Same as overt event but more people affected and more serious effects.	Must have sensor	Readily available	Seconds (on-site)	Decontamination likely required.	Long-term service suspension until safe levels achieved.	Short-term broad suspension until know limited of spread, long-term suspension in contaminated areas.
Chemical								
Low Persistence	Immediate to hours, temporary distress to mortality. Treatment can reduce health effects.	Same as overt event but more people affected and more serious effects.	Symptoms seen immediately to hours later	Readily available	Seconds (on-site)	Little to no decontamination except for very large releases.	Short-term suspension of service until safe levels achieved.	Short-term suspension of service until safe levels achieved.
High Persistence						Decontamination likely required.	Medium-term suspension until safe levels achieved.	Short-term broad suspension until know limit of spread, medium suspension in contaminated areas.
Biological								
High Persistence, Low Contagiousness	Symptoms typically delayed for days. *Some agents:* Effective treatment if initiated prior to symptoms. *Other agents:* Treatment limited to supportive care.	Same as overt but reduced treatment effectiveness with delayed application.	Symptoms seen days to weeks later if no analysis	Available for some agents	*Some agents:* Minutes (on-site) *Other agents:* Days for lab identification	Decontamination likely required.	Medium-term suspension of service until safe levels achieved.	Short-term broad suspension until know limit of spread, medium suspension in contaminated areas.
Low Persistence, Low Contagiousness						Decontamination may not be needed, depends on amount released.	Short-term suspension of operations depending on the amount and stability of agent.	Short-term suspension if the released agent has not already lost infectivity.
Low Persistence, High Contagiousness		Same as above with outbreaks around the country and world.				Broad, medium-term service suspension until infected people are isolated and safe levels achieved.	Very broad, medium-term suspension of service until infected individuals are isolated and safe levels achieved.	Possible very broad, medium term suspension of services until infected individuals are isolated and safe levels achieved.

or manufacture and probability of successful delivery to the target. Although radiological and biological agents can affect a broader geographic area than chemical agents, obtaining the most potent forms of chemical agents is generally easier than for biological and radiological agents.

For all agents, effective dispersal is a substantial difficulty. These difficulties are exemplified in the multiple attacks by the Aum Shinrikyo cult in Tokyo first using biological agents without success and then chemical agents with modest success (i.e., diluted chemical and crude, relatively poor dispersion).

The nature of risk is that while the most likely types of events over an extended time may be predicted, the next single event type cannot be predicted. The 2001 anthrax mailings in the United States exemplified this problem in that the agent used was a highly weaponized bacterial strain that is very difficult to obtain or produce. Therefore, this specialized form was not among the more likely agents to be used in a terrorist act, but it was used nevertheless. Thus, all credible event types must be given serious consideration and response planning, regardless of their relative likeliness to occur.

The general characteristics of CBR releases are summarized in Table 2-15 in terms of health effects, agent identification, decontamination requirements, and potential effect on transportation. CBR subcategories are delineated based on the agents' persistence and contagiousness. Persistence refers to the extent of time a released agent remains a threat in an open environment; and contagiousness denotes the potential to multiply within an infected person and then spread from person to person (i.e., a characteristic unique to biological agents). Both of these factors have a profound influence on the duration of health risks, the scope of human health effects, and the related duration and magnitude of effects on the transportation system.

For most CBR agents, the magnitude of health effects and related effects on transportation vary greatly for overt and

TABLE 2-16 Relative Vulnerabilities of the Transportation System to Releases of Persistent Chemical, Biological, and Radiological Agents (Persistence = more than 24 hours to substantially degrade in an open environment)

Vulnerability	Ability to Retain Contamination			Difficulty of Decontamination			Ability to Spread Contamination		
	Chem[1]	Bio[2]	Rad[3]	Chem[1]	Bio[2]	Rad[3]	Chem	Bio	Rad
Transportation Path									
Road	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Track	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Tarmac	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Air	Low	Low	Low	Low	Low	Low	High[4]	High[4]	High[4]
Waterway	Low	Low	Low	Low	Low	Low	High[4]	High[4]	High[4]
Indoor or Underground Stations/ Terminals									
Smooth surfaces	High	High	High	Medium	Medium	High	Low	Low	Low
Porous surfaces[5]	High	High	High	Medium	High	High	Low	Low	Low
HVAC system	Medium	Medium	Medium	Low	Low	Low	High	High	High
Outdoor Stations/ Terminals									
Smooth surfaces	Medium	Medium	High	Low	Low	Medium	Low	Low	Low
Porous surfaces[5]	Medium	Medium	High	Medium	Medium	High	Low	Low	Low
Vehicles/ Vessels									
Smooth surfaces	Medium	Medium	Medium	Low	Low	Medium	Low	Low	Low
Porous surfaces[5]	High	High	High	High	High	High	High[6]	Medium	Medium
HVAC system	Medium	Medium	Medium	Low	Low	Low	High	High	High
Contents									
Crew/ Passengers	Medium	Medium	Medium	Medium	Medium	Medium	High[6]	Medium[7]	Medium
Cargo/ food/ water	High	High	High	Medium	Medium	High	High	High	High

[1] Persistent chemicals include some chemical weapons agents (e.g., mustard agents, VX). Most transported industrial chemicals and many chemical agents are not persistent; thus ability to retain contamination and the difficulty of decontamination is low for many chemicals due to their non-persistence.

[2] Persistent biological agents include Anthrax spores, mycotoxins (T2 or yellow rain), and the causative agent of Q-fever, none of which are very contagious. Most other biological agents are not persistent in an open environment, and the ability to retain contamination and the difficulty of decontamination would be relatively low.

[3] Most radiological agents are persistent. For those that are not persistent the ability to retain contamination and the difficulty of decontamination would be relatively low.

[4] Ability to spread contamination is high, but the contaminant may be relatively quickly diluted below levels of concern.

[5] Porous surfaces include corroded metal, cement, rubber, carpet, fabric, etc.

[6] Most persistent chemical agents of concern (i.e., mustard and VX) are oily liquids that may adhere to skin, clothing, and other porous surfaces better than solid particle forms of radiological and biological agents.

[7] High if the biological agent is contagious (i.e., influenza, pneumonic plague, smallpox, some hemorrhagic fevers).

covert releases (Table 2-15). An overt event is quickly recognized because of accompanying signs such as an explosion, visible plume, odor, or warning letter. Overt events generally solicit better targeted and measured responses from all sectors, including transportation. In contrast, a covert event is not quickly recognized, which causes delays in agent identification, delivery of emergency response, and implementation of mitigating measures.

The rapid onset of symptoms from most chemical agents in conjunction with rapid detection technology reduces the differences in effects between overt and covert chemical releases. In contrast, firm identification of biological agents often takes days after an event is suspected, and in a covert event, the development of suspicions of an event may also take days to weeks. During such delays, persistent biological agents and infected individuals continue to spread aided by the transportation system.

Rapid detection of radiological agents allows for relatively rapid determination (i.e., within hours) of contaminated areas (Table 2-15). However, in a covert radiological event with low enough doses of radiation for delayed symptoms, the hazard may not be detected for years, or until a serendipitous measurement of radiation is made. In general, the speed with which CBR contamination can be identified affects the duration of broader, shorter-term effects of a CBR release on transportation, and the difficulty of decontamination of the CBR agent largely determines how long areas of the transportation system may be isolated and restricted.

Table 2-16 summarizes the transportation system's relative vulnerabilities with respect to the system's ability to retain contamination of persistent CBR agents at levels that may affect human health, the difficulty of decontamination, and the ability to spread these contaminants.

In enclosed areas (e.g., passenger compartments and buildings), the ventilation system may help disperse CBR agents, so shutting down these systems is a commonly recommended first-response. In open, outdoor areas, concerns about wind spread of contamination may be off set by factors such as the ability of wind to enhance evaporation of liquid agents and broadly dilute vapors and small particles to safe levels and degradation of many chemical and biological agents by sunlight. These same factors may facilitate decontamination of chemical and biological agents in open environments; however, runoff control of decontamination chemicals may be more challenging.

In general, porous surfaces have greater ability to retain contamination than smooth surfaces. Porous surfaces such as fabric, rubber, and corroded metal have microscopic pits and valleys that may retard natural degradation and hinder decontamination efforts.

After decontamination, the only CBR agents that may be spread further are the subset of biological agents that are contagious. For many diseases, the most contagious stages occur during the period that infected individuals are obviously sick and often confined to bed. The transportation system may facilitate the dispersal of infected individuals before contagious stages and the possibility of contagious passengers infecting other passengers.

CHAPTER 3

EMERGENCY RESPONSE PLANS, OPTIONS, AND STRUCTURE

This chapter presents a summary of the different U.S. transportation modes. The summary includes functional, operational, and control characteristics of these modes, which will assist in meeting the ultimate objective of this research, which is to develop a guide that will help state and local transportation officials to develop their transportation response options in the case of an extreme event.

The U.S. transportation system carries both freight and people, transported using the following modes:

- Highway,
- Maritime,
- Rail,
- Air, and
- Mass transit.

The last category is unique in that it uses the former modes of transportation, but is limited to the transport of people. The operations of the mass transit system are quite different from freight or personal transportation, thus, the options for use of this system in the case of extreme events is considered separately.

Each of the five transportation mode summaries is divided into the following subsections:

- Definitions used to describe the system;
- National system size and characteristics;
- System use under normal operations;
- System financing as it relates to security funds and emergency options;
- General organization from a management perspective;
- General operations under normal conditions;
- Emergency plans in the system and organization during emergency events;
- Historical emergency actions; and
- Summary matrixes of operations and traffic, and emergency options, limits, and authority.

3.1 THE HIGHWAY SYSTEM

3.1.1 Definitions

The U.S. highway system is approximately 160,000 miles (256,000 kilometers) of roadway important to the nation's economy, defense, and mobility. The National Highway System (NHS) was developed by the Department of Transportation (DOT) in cooperation with the states, local officials, and metropolitan planning organizations (MPO). The NHS includes several subsystems of roadways that overlap: arterials and other road classifications (that are part of the national road network, but of which only a small part of the mileage falls within the NHS).

Arterials

These roadways provide the highest level of mobility, at the highest speed, for long and uninterrupted travel. Arterials typically have higher design standards than other roads. They often include multiple lanes and have some degree of access control. The rural arterial network provides interstate and inter-county service so that all developed areas are within a reasonable distance of an arterial highway. FHWA subclassifications for arterials in the NHS include the following:

- Interstate. The Eisenhower Interstate System, as originally established by the Federal-Aid Highway Act of 1956, retains a separate identity within the NHS. The Interstate System connects, as directly as practicable, principal metropolitan areas, cities, and industrial centers; serves the national defense; and connects at suitable border points with routes of continental importance.
- Other Principal Arterials. These are highways in rural and urban areas that provide access between an arterial and a major port, airport, public transportation facility, or other intermodal transportation facility. Almost all urban areas with more than 50,000 people, and most urban areas with more than 25,000 people, are connected by principal arterial highways that may or may not be part of the Interstate System.
- Strategic Highway Network (STRAHNET). This network of highways is important to U.S. strategic defense policy; it provides defense access and continuity and emergency capabilities for defense purposes.
- Major Strategic Highway Network Connectors. These are highways that provide access between major military installations and highways that are part of the Strategic Highway Network.

- Intermodal Connectors. These highways provide access between major intermodal facilities and the other subsystems making up the NHS.

Other Road Classifications

These are part of the national road network, but only a small portion of the mileage falls within the NHS.

- Minor arterials. These are roads smaller than principal arterials that connect small communities (e.g., populations < 25,000).
- Collectors. These roads provide a lower degree of mobility than arterials. They are designed for travel at lower speeds and for shorter distances. For the most part, collectors are two-lane roads that collect and distribute travel from the arterial system. The collector system has two subsystems: major and minor collectors. Major collectors serve larger towns not accessed by higher order roads and important industrial or agricultural centers that generate significant traffic but are not served by arterials. In urban areas, the collector system provides traffic circulation within residential neighborhoods and commercial and industrial areas. Unlike arterials, collector roads may penetrate residential communities, distributing traffic from the arterials to the ultimate destination for many motorists. Urban collectors also channel traffic from local streets onto the arterial system.
- Local roads. These roads represent the largest element in the American public road network in terms of mileage. For rural and urban areas, all public road mileage below the collector system is considered local. Local roads provide basic access between residential and commercial properties and connect with higher order highways.

3.1.2 System Size

"Lane miles" is defined as road mileage, with parallel lanes counted separately and thus is greater than miles in terms of travel distance. In 2000, more than 50 percent of the U.S. total lane miles were rural local centerline roads. Principal arterials, including the interstate, composed only 7 percent of the national total lane miles, while major and minor collectors represented 15 and 9 percent of the national total lane miles, respectively. Table 3-1 shows lane miles and the percentage of the U.S. total by road classification (i.e., functional system) and area population size.

Bridges in the national road system may represent particular points of interest because they typically take more time and money to replace than roadway. Of the 587,146 highway bridges in the United States in 2000, 77.6 percent were in rural communities and 22.4 percent were in urban areas. Examining structures by numbers gives all bridges in the network equal priority. Thus, a small local bridge is counted the same as a large urban bridge such as New York's George Washington Bridge or San Francisco's Golden Gate Bridge. Structure size can be accounted for by using bridge deck area. Table 3-2 describes, by functional classification and area population, the number of highway bridges and the percentage of the total number of bridges and total deck area.

3.1.3 System Use

Highway transportation in the United States plays a significant role in two major areas: providing personal mobility to households and facilitating freight movement. The use of private automobiles on the U.S. highway network provides Americans with a high degree of personal mobility. Automobile transportation allows people to travel where they want, when they want, and with whom they want. The freedom

TABLE 3-1 Highway Lane Miles and Percent of U.S. Total by Functional System and Area Population Size, 2000

Functional System	Urban (pop. > 50,000)		Small Urban (pop. 5,000 – 49,999)		Rural (pop. <5,000)		Total	
	Lane miles	% U.S. Total	Lane miles	% U.S. Total	Lane miles	% U.S. Total	Lane miles	% U.S. Total
Interstate	66,507	0.8%	7,626	0.1%	135,000	1.6%	209,133	3%
Other Principal Arterial	37,113	0.4%	4,627	0.1%	253,192	3.1%	294,932	4%
Minor Arterial	148,077	1.8%	37,702	0.5%	287,605	3.5%	473,384	6%
Major Collector	180,434	2.2%	45,208	0.5%	872,647	10.6%	1,098,289	13%
Minor Collector	143,620	1.7%	44,525	0.5%	544,976	6.6%	733,121	9%
Local	961,484	11.6%	238,684	2.9%	4,230,598	51.3%	5,430,766	66%
Total	1,537,235	18.6%	378,372	4.6%	6,324,018	76.6%	8,239,625	100%

(Source: Highway Performance Monitoring System)

TABLE 3-2 Number of Highway Bridges and Percent of U.S. Total Number and Deck Area by Functional System, 2000

Functional System	Urban			Rural		
	Number of Bridges	% U.S. Total Number	% U.S. Total Deck Area	Number of Bridges	% U.S. Total Number	% U.S. Total Deck Area
Interstate	27,882	4.7%	19.4%	27,797	4.7%	8.2%
Other Arterial	63,177	10.8%	26.6%	74,796	12.7%	15.7%
Collector	15,038	2.6%	2.8%	143,357	24.4%	13.5%
Local	25,684	4.4%	3.6%	209,415	35.7%	10.3%
Total	131,781	22.4%	52.4%	455,365	77.6%	47.6%

(Source: National Bridge Inventory)

accorded by automobiles and highways accounts in large part for the enormous popularity of automobile travel. One hundred million U.S. households generate more than one billion person trips and over nine billion person miles of travel in a typical day.

The highway system is also a key conduit for freight movement, accounting for 54 percent of total freight transport by weight and 83 percent by value in 1998. Between 1993 and 1997, the weight of commodities shipped by truck from U.S. establishments increased 20.6 percent. The average miles traveled by trucks grew at an average annual rate of 4.0 percent per year during this period (USDOC Census 1997). The value of goods transported by truck has increased, while the weight of goods shipped has declined.

In addition to personal mobility and freight movement, transit modes such as buses, vanpools, and demand-response services share roadways with private automobiles and commercial vehicles and are affected by highway pavement and traffic conditions.

3.1.4 Financing

Highway financing is provided by federal, state, and local sources. The federal-aid highway program is a federally assisted, state-administered program that distributes federal funds to the states for the construction and improvement (i.e., operation and maintenance) of urban and rural highway systems. Federal-aid highway projects are developed, contracted, and supervised by the states. Roads remain under the administrative control of the state or local government responsible for their operation and maintenance. The federal-aid highway program is financed from the proceeds of motor-fuel and other highway-related excise taxes deposited in the Federal Highway Trust Fund (HTF). Table 3-3 shows revenues used for highways in 1999. More than one-half of revenues used for highways were from user-taxes (e.g., gasoline taxes). Table 3-4 shows revenues used to fund highways in 1999. The category of "law enforcement and safety" represented about 9 percent of the total disbursements for highways in 1999.

Funds are apportioned to states in accordance with legislated formulas that include factors such as Interstate lane-miles, travel, and commercial vehicle contributions to the Highway Trust Fund. For most programs, these funds are matched by state or local governments on an 80 percent federal share to a 20 percent state share basis. State and local governments also receive funds for their highway activities from programs administered by other federal agencies. Some federal funds are distributed through state governments to local governments. Federal agencies' direct work on highways represents only a small portion of federal assistance to highways.

Most local governments are constrained by their state governments with respect to revenues generated by the taxation of real and personal property. Because there are limits to the amount of revenue that can be derived from property taxation, many states share revenues with local governments. Local highway-user taxation, when permitted by the state, is usually in the form of local option taxes on motor fuel. With a local option tax, the state allows local governments to decide whether to levy a tax in addition to the state tax rate.

TABLE 3-3 Revenues Used for Highways, All Levels of Government, 1999

Revenue Source		$ (millions)
Highway-User Tax Revenues[1]	Federal[2]	25,083
	State	42,029
	Local	1,746
	Total	68,857
Road and Crossing Tolls		5,132
Appropriations from General Funds		17,185
Property Taxes		5,809
Other Imposts		6,382
Miscellaneous Receipts [3]		6,775
Bond Receipts [4]		11,274
Total Receipts		121,413

(Source: FHWA)

[1] Excludes amounts allocated for collection expenses and nonhighway purposes.

[2] Amounts reflect Highway Trust Fund revenues attributable to highway-user taxes that were expended for highways in each state, excluding territories.

[3] Includes interest earned on Highway Trust Fund reserves.

[4] Excludes short-term notes and refunding bond issues.

TABLE 3-4 Total Disbursements for Highways, All Units of Government, 1999

Disbursement Type [1]		$ (millions)
Capital Outlay	State Highways	41,264
	Local Highways	15,712
	Fed. Roads and Unclassified	246
	Total	57,222
Maintenance and Services	State Highways	11,964
	Local Highways	17,964
	Fed. Roads and Unclassified	69
	Total	29,997
Administration and miscellaneous		9,129
Highway Law Enforcement and Safety		10,393
Interest		4,349
Bond Retirement [2]		4,914
Total Disbursements		116,005

(Source: FHWA)

[1] Disbursements are classified by system on which expended, rather than by expending agencies; e.g., capital outlay on local rural roads includes expenditures from federal, state and local funds. Data includes estimates.

[2] Excludes short-term notes and refunding bond issues.

3.1.5 General Organization

Publicly owned highways and bridges are those owned by the federal, state, and local governments. States own almost 20 percent of the nation's road system. State governments include a DOT or equivalent responsible for road development and maintenance. The inclusion of law enforcement authority within the DOT varies among states. The federal government has control over about 3 percent of the network, primarily in national parks and forests and on Native American reservations. More than 77 percent of U.S. roads are owned by local governments (e.g., counties, cities, and towns).

3.1.6 Operations

Each state pays for the maintenance, law enforcement, and construction of highways within its boundaries, and each state attempts to ensure receipt of taxes for using its highways. States establish vehicle safety regulations, including licensing requirements and speed limits. Each state can also establish width and weight regulations, within certain federal guidelines, for trucks that operate within its jurisdiction.

3.1.7 Emergency Plans and Organization

The state DOT, along with the state emergency management office, develops emergency plans that include highways. Emergency planning includes preparedness, awareness, and response activities. Preparedness activities are designed to provide a basis to respond to an event; they include coordinating plans, predeploying resources, and providing public information to support rapid and effective implementation of response measures. Examples include readying and publicizing evacuation routes prior to a hurricane and raising security levels on critical transportation infrastructure in response to warnings of increased threat levels. During the preparedness phase of emergency management, transportation agencies typically support the development and revision of

- State emergency operations plans (EOPs);
- Local/regional hazard-specific plans;
- Mutual aid and other support agreements;
- Documentation of transportation agency roles in the ICS and community Emergency Operations Center (EOC);
- Evacuation plans at the county, state, and multistate levels;
- Plans to manage the immediate transport of supplies to support shelter-in-place strategies; and
- Training.

Preparedness activities can also include participating in exercises and coordinating and planning meetings, as well as activities designed to establish and improve interagency and public communication before, during, and after an event.

Awareness activities include gathering and reporting information on potential emergency events, as well as informing agencies and the general public about the occurrence of an event. Event warnings or alerts can include notifications that a major event may occur, either through weather forecasting (e.g., natural disaster), heightened readiness at the local/regional level (e.g., special event, possible strike, or civil unrest), or the DHS's Homeland Security Advisory System. Whether warning is available or not, the identification of the occurrence of an event or series of events with the potential to disrupt the transportation system must be provided. Among the awareness activities performed by transportation agencies are

- Use of surveillance systems to detect indicators of a potential emergency, an emergency that is occurring, or an emergency that has occurred; and
- Verification by field personnel that an emergency event is occurring or has occurred and communication of relevant information to all responding agencies.

Response activities cover a wide range of tasks designed to minimize loss of life and property as a result of an emergency event. Transportation agencies implement a number of response activities during an emergency event, including the following:

- Advising law enforcement on access for transportation personnel assessing damage;

- Performing damage assessment responsibilities for affected transportation system elements;
- Coordinating assessments and decisions on the operational capabilities of the transportation system;
- Making decisions regarding closures, restrictions, and priority repairs;
- Providing assistance in determining any potential hazards at the scene;
- Initiating traffic management operations and control strategies;
- Assigning personnel to EOC(s) to help coordinate disaster response and recovery efforts;
- Addressing first responder transportation needs;
- Providing field support for emergency responders, integrated through ICS and communicated and coordinated with the traffic management center (TMC);
- Assigning transportation resources to move materials, personnel, and supplies as requested by responders;
- Supporting hazardous materials containment assessments in coordination with the ICS; and
- Attending briefings at incident sites on situations, incident action plans, response objectives, and strategy.

Recovery activities are concentrated on restoring essential services following an emergency event. Activities include implementing plans to reopen closed segments of the transportation system to allow the return of evacuated persons to their communities and rerouting traffic to ensure that sufficient capacity to meet regional demand is provided. Other recovery-related activities performed by transportation agencies include

- Initiating priority clean-up, repair, and restoration activities;
- Coordinating roadway clearance activities;
- Prioritizing recovery operations and performing emergency repairs in the disaster area;
- Coordinating with other jurisdictions that are managing, supporting, or affected by the repair activities;
- Assisting in the design and implementation of alternate transportation services;
- Coordinating with efforts to restore utilities;
- Supporting decontamination of hazardous materials contractors and clean-up crews;
- Assisting state and local governments in determining the most viable transportation networks to, from, and within the disaster area and regulating the use of those networks;
- Providing highway clearances and waivers required to expedite transportation of high-priority materials; and
- Providing public information/traveler alerts on transportation status by monitoring re-entry routes.

In summary, the scope and responsibilities of transportation agencies regarding emergency response include three general areas: (1) operating the transportation system before, during, and after an emergency event; (2) delivering information on transportation system status to other public agencies and the general public before, during, and after an event; and (3) providing logistical support to other public agencies and the general public.

3.1.8 Historical Emergency Actions

There is historical experience in taking emergency actions to alter highway use for evacuations because of natural events such as hurricanes and floods. During these events, in-bound entrance ramps can be closed with gates and in-bound lanes are reduced or entirely eliminated and redesignated as out-bound lanes. In the southeastern coastal cites where there are greater hurricane risks, evacuation routes are displayed in places ranging from local newspapers, to the internet, media broadcasts, and telephone book community information sections. The evacuating state DOT coordinates activities with adjacent states, providing them with estimates of evacuation traffic flow.

After the Northridge earthquake in 1994, California's DOT responded by assessing highway infrastructure condition, determining its soundness, and developing alternative routes where necessary. In addition to modifying highway traffic flow and assessing highway soundness, the state DOT has provided trucks, personnel, and sand bags as requested by incident command centers in response to various emergencies.

3.1.9 Highway System Summary Matrix

Table 3-5 summarizes highway operational sequences, traffic flow, and historical emergency response. Table 3-6 summarizes highway control options, operational limits, and existing authority.

3.2 THE MARITIME SYSTEM

3.2.1 Definitions

For this project, the U.S. maritime transportation system (MTS) is defined in accordance with the U.S. Coast Guard (USCG) and the Army Corps of Engineers as consisting of 95,000 miles of coast line, including the Great Lakes and inland waterways, with more than 361 ports. U.S. waters are all waters extending from 12 nautical miles off the coast inland. State waters are waters contained solely within one state that are never navigated commercially or were not created by the U.S. Army Corps of Engineers.

Coastal trade is defined in the Jones Act as picking up cargo in one U.S. port for delivery to another U.S. port. Liner trade defines the movement of cargo vessels that adhere to a set schedule of port visits and departures. Tramp trade

TABLE 3-5 Highway Operational Sequences, Traffic Flow, and Historical Emergency Response

Operational Sequences	Traffic Flow		Historical Emergency Response	
	Traffic Types	Traffic Patterns	Short Term (2 hr)	Long Term (>2 hr)
Personal: Private passenger cars and light duty trucks for personal travel. Peak demand during morning and afternoon commute hours with travel during weekdays often higher than during weekends. **Freight:** Privately owned heavy duty trucks hauling freight. Truck volume generally uniform throughout the day and generally lower on weekends than weekdays.	**Normal:** A mix of vehicle types and travel demand. **Constraining Emergencies:** General traffic reduced during severe weather (e.g., snow, hurricane). In extreme cases, prohibit travel on public roads to facilitate emergency equipment access. **Expanding Emergencies:** Use evacuation routes to expand exit capacity. Modify traffic control devices (e.g., traffic signals) to manage demand. Reroute traffic to facilitate emergency response.	**Rush Hours:** Toward urban areas, schools, and work centers. **Off-Peak:** To and from schools, shopping, entertainment, etc. **Emergencies:** Route vehicles generally away from emergency area; first responders toward emergency area.	**Eliminate Access:** Prohibit vehicles from accessing site. **Reroute Traffic:** Establish routes around site. **Establish Evacuation Route:** Identify evacuation routes to provide vehicles with routes away from scene. **Other Options:** Modify traffic control to provide access to emergency vehicles (e.g., traffic signal priority); provide traveler information regarding alternative routes. **Reroute:** Modify routes as needed.	**Same as short term and:** **Repair**/**Construct** roads and bridges.

TABLE 3-6 Highway Control Options, Operational Limits, and Existing Authority

Control Options		Operational Limits		Existing Authority
Short Term (2 hr)	**Long Term (>2 hr)**	**Short Term (2 hr)**	**Long Term (>2 hr)**	**Options**
◆ Reroute traffic ◆ Change traffic signalization ◆ Institute reverse lanes ◆ Distribute traveler information ◆ Execute incident management plans	**Same as short term and:** **Implement evacuation plans**	**Reroute traffic**—limited feasible routes **Change traffic signalization**—hardware and software limits **Institute reverse lanes**—geometry and access limits **Distribute traveler information**—accuracy and availability **Execute emergency plans**—limited equipment and staff	**Same as short term and:** **Implement evacuation plans**—coordination of routes and information across jurisdictions **Fuel Access**—suspended or delayed fuel deliveries may limit highway access.	**Reroute traffic**—state/local public safety agencies **Change traffic signals**—state/local transportation agency **Institute reverse lanes**—state transportation agency **Distribute traveler information**—state/local transportation agency **Execute incident management plans**—state/local transportation agency

defines the movement of vessels that comply with specific delivery orders. Such vessels may remain at anchor for extended periods of time awaiting their next transport order.

Types of maritime vessels include

- Foreign vessels. Such vessels are prohibited by the Jones Act from participating in coastal trade. These vessels are built, substantially modified, owned, controlled, or crewed by non-U.S. personnel or businesses.
- U.S.-flagged vessels. These are defined as vessels built, controlled, crewed, and primarily maintained by U.S. personnel or business. Certain exemptions to this criterion are routinely included in congressional legislation for specific vessels.
- Ferries. These are vessels designed to transport passengers or passengers and vehicles on fairly short (less than a day) scheduled routes. Most ferries operating in U.S. waters are U.S. flagged.
- Cruise ships. These are designed to transport passengers for longer periods of time. Most cruise ships are foreign vessels.
- Liners. These are freight vessels that carry cargo according to a fixed scheduled of routes and port calls. Most containerized and some breakbulk cargo fall in this category.
- Tramps. These are chartered freight vessels that carry dry cargo (mainly dry bulks such as coal, grain, and fertilizers, as well as steel and, in some cases, automobiles).
- Tankers. These are vessels that carry bulk liquid cargo, such as crude oil.

3.2.2 System Size and Modes

It is misleading to define the U.S. MTS simply by reporting the number of U.S. flagged vessels. An average of 7,500 foreign ships call on U.S. ports each year. These foreign ships account for 95 percent of the passenger ships (mainly cruise ships) and 75 percent of the cargo ships operating in U.S. waters. However the flag of the vessel no longer represents the nation of the vessel owners. Most of the cruise ships visiting our ports are actually owned by a U.S. corporation; for example Miami-based Carnival Cruise Lines is the largest cruise line in the world. Although not as dramatic in percentage, the number of foreign tankers entering the U.S. that are actually owned by U.S. corporations is also high. Table 3-7, describes the vessels with a U.S. flag registry.

Because of many economic factors, the actual U.S. flag fleet has become primarily one of tugs, barges, excursion boats, and ferries, with a few deep draft cargo vessels serving U.S. states and possessions (e.g., Alaska, Hawaii, Guam, and Puerto Rico).

The major U.S. components of the MTS are its port and the inland waterway vessels. Table 3-8 lists the top 15 ports in the United States. based on total cargo, foreign trade cargo, and containers. Bulk cargo (e.g., coal, oil, and grain) is worth far less per ton than containerized cargo; thus cargo tonnage alone does not reflect relative economic value. Table 3-9 lists the value and weight of foreign freight cargo based on cargo vessel type, where liners are largely transporting containers (i.e., ready for intermodal transport).

3.2.3 System Use

According to the USCG, more than 95 percent of the overseas trade that comes in or out of the United States moves by ship. U.S. ports and waterways handle more than 2 billion tons of both domestic and foreign commerce, including the daily importation of 9 million barrels of oil. Cargo moving through the MTS contributes more than $742 billion to the U.S. gross domestic product and creates employment for more than 13 million individuals.

Ninety percent of all equipment and supplies for Operation Desert Storm was shipped from U.S. strategic ports via U.S. inland and coastal waterways. Commercial transportation assets decrease the cost and environmental impact of meeting military

TABLE 3-7 Summary of the United States Shallow and Deep Draft Vessels by Vessel Type for 2001

Vessel Type		Shallow Draft Vessels				Deep Draft Vessels		
Vessel Type	Number	% Total of Type	Average Draft	Average Age	Number	% Total of Type	Average Draft	Average Age
Vessels (total)[2]	**39,945**	**96.2**	**9**	**20**	**1,557**	**3.8**	**21**	**20**
Self-Propelled (total)	**7,615**	**89.7**	**8**	**26**	**871**	**10.3**	**23**	**21**
Dry Cargo (total)	732	78.7	7	24	198	21.3	31	24
Dry Bulk	6	8.2	11	36	67	91.8	30	28
Containership	0	-	-	-	68	100.0	37	19
General Cargo	209	86.0	9	30	34	14.0	29	21
Specialized	517	94.7	6	22	29	5.3	18	27
Passenger	724	99.2	5	23	6	0.8	21	20
Offshore Support	1,465	93.5	8	19	102	6.5	17	7
Tanker	23	19.2	9	44	97	80.8	40	21
Towboat	4,671	90.9	8	29	468	9.1	17	22
Non-Self-Propelled (total)	**32,327**	**97.9**	**9**	**18**	**685**	**2.1**	**19**	**20**
Dry Barge (total)	28,474	98.6	9	18	416	1.4	18	18
Dry Covered	13,600	98.6	9	16	192	1.4	20	11
Dry Open	8,649	99.2	9	16	68	0.8	17	34
Lash/Seabee	1,184	100.0	9	22	0	-	-	-
Deck	4,927	97.6	8	23	120	2.4	16	21
Other Dry[3]	114	76.0	9	25	36	24.0	16	19
Tank Barge (total)	3,853	93.5	10	23	269	6.5	21	23
Single Hull	587	84.5	10	32	108	15.5	21	26
Double Hull	2,642	97.2	10	21	75	2.8	23	16
Other Tank[4]	624	87.9	9	24	86	12.1	21	25

(Source: U.S. Army Corps of Engineers)

[1] Based on the loaded draft of the vessel; shallow draft is defined as less than or equal to 14 feet and deep draft is greater than 14 feet.

[2] Total is greater than the sum because of 4 unclassified vessels and 86 vessels with unknown draft; includes vessels available for operation.

[3] Includes dry cargo barges that may be open or covered, railroad car, pontoon, RO-RO, container, or convertible.

[4] Includes tank barges that may be double sided only, double bottom only, or not elsewhere included.

transportation requirements. Ships and barges have the fewest accidental spills or collisions of all forms of transportation. They routinely load and unload millions of barrels of petroleum and tons of coal, grain, chemicals, and other essential products throughout the United States, from Alaska to Maine.

The inland portion of the MTS includes nearly 12,000 miles of commercially navigable inland and coastal waterways and more than 630 million tons of cargo per year. Moving the same volume over land would require 6.3 million rail carloads or 25 million truckloads.

In 1997, the cruise passenger industry spent $6.6 billion on goods and services in the United States, which generated 176,000 jobs and had an estimated total economic impact of $11.6 billion. In 2003, it is estimated that there were approximately 163 foreign-flag passenger vessels operating from U.S. ports, each carrying 1,000 to 5,000 persons on board, and all combined, carrying more than 6.5 million passengers annually.

About 78 million Americans participated in recreational boating in 1997, using 16 million boats of all types and spending $19 billion for new and used boats, accessories, and memberships in 8,000 yacht and boat clubs. Millions of people annually use commercial passenger vessels that provide sightseeing, excursion, dining, gaming, wind jamming, whale watching, and nature cruises.

Ferries and high-speed vessels increasingly provide an environmentally sound alternative to cars. Ferryboat riders are often commuters. The largest capacity ferry systems are in the states of Washington and New York, although nearly every state has a private or government-run ferry service. In Puget Sound, ferries carry 23 million passengers each year; in Alaska, ferries are essentially the highways to and from homes and businesses. Private ferries must turn a profit while taxpayers subsidize public systems such as in New York and Washington. Table 3-10 summarizes the U.S. ferry fleet passenger capacity.

3.2.4 Financing

In the United States, most vessel and marine terminal costs are privately funded. The federal government maintains some infrastructure, such as vessel locks on the inland waterways,

TABLE 3-8 Top U.S. Ports Based on Total Cargo, Foreign Trade Cargo, and Container Traffic

Total Cargo, 2001			Foreign Trade Cargo, 2001			Container Traffic, 2002		
Rank	Port	Tons (mil)	Rank	Port	Tons (mil)	Rank	Port	TEUS
1	South Louisiana	212.6	1	Houston, TX	120.6	1	Los Angeles, CA	6,105,864
2	Houston, TX	185.1	2	South Louisiana	95.7	2	Long Beach, CA	4,524,036
3	NY/NJ	137.5	3	NY/NJ	67.3	3	New York/New Jersey	3,749,014
4	New Orleans, LA	85.6	4	Beaumont, TX	62.0	4	Oakland, CA	1,707,827
5	Beaumont, TX	79.1	5	Corpus Christi, TX	53.9	5	Charleston, SC	1,592,834
6	Corpus Christi, TX	77.6	6	Long Beach, CA	51.6	6	Tacoma, WA	1,470,826
7	Huntington, WV	76.7	7	New Orleans, LA	50.3	7	Seattle, WA	1,436,872
8	Long Beach, CA	67.6	8	Los Angeles, CA	45.0	8	Hampton Roads, VA	1,437,779
9	Texas City, TX	62.3	9	Texas City, TX	44.1	9	San Juan, PR	1,393,627
10	Baton Rouge, LA	61.4	10	Hampton Rds, VA	33.7	10	Savannah, GA	1,327,939
11	Plaquemines, LA	60.7	11	Philadelphia, PA	32.9	11	Houston, TX	1,159,789
12	Pittsburgh, PA	53.0	12	Lake Charles, LA	31.9	12	Miami, FL	980,743
13	Lake Charles, LA	52.8	13	Mobile, AL	28.0	13	Honolulu, HI	945,460
14	Los Angeles, CA	51.4	14	Portland, ME	26.5	14	Jacksonville, FL	683,836
15	Hampton Rds, VA	51.2	15	Baltimore, MD	25.4	15	Port Everglades, FL	554,041

(Source: American Association of Port Authorities (AAPA))

TEUS = "Twenty-foot Equivalent Units" (i.e., 20-ft long container equivalents)

TABLE 3-9 Foreign Waterborne Cargo Summary, Year-to-Date, August 2003, Value, Weight and Value to Weight Ratio

Type of Service	Imports			Exports			Total		
	Value (million $)	Weight (thousand tons)	Value/ weight ($/ton)	Value (million $)	Weight (thousand tons)	Value/ weight ($/ton)	Value (million $)	Weight (thousand tons)	Value/ weight ($/ton)
Liner	236,233	69,610	3,394	88,830	47,639	1,865	325,063	117,249	2,772
Tanker	83,314	443,984	188	10,618	38,841	273	93,931	482,826	195
Tramp	75,904	130,771	580	32,543	141,443	230	108,447	272,214	398

and it provides some funding for dredging certain ports and waterways. Since the terrorist attacks of September 11, 2001, the federal government has also provided funds to operators in the MTS to assess and upgrade security.

According to the American Association of Port Authorities (AAPA), in 1998, port authorities invested nearly $1.5 billion to update their facilities, including $154 million for general cargo, $507 million in investments for containers, $260 million on infrastructure improvements, and $152 million for dredging. Between 1999 and 2003, it has been projected that ports will spend just over $9 billion.

TABLE 3-10 U.S. Ferry Fleet by Passenger Capacity, 2001

Passenger Capacity	Number of Vessels	% Total
0 – 50	120	19.3
51 – 100	154	24.8
101 – 200	98	15.8
201 – 350	57	9.2
351 – 500	60	9.6
501 – 1,000	71	11.4
Over 1,000	27	4.3
Unknown	35	5.6
Total Ferry Fleet	**622**	**100.0**

(Source: WCSC survey and DOT National Ferry Study)

The U.S. DOT Maritime Administration (MARAD) provides some funding to the operators of U.S. flag vessels, which helps off set the higher labor and vessel costs associated with U.S. regulatory requirements. In return, MARAD retains certain rights to use these vessels in times of national need.

3.2.5 General Organization

According to the AAPA "The U.S. public port industry consists of more than 100 public port authorities and agencies located along the Atlantic, Pacific, Gulf and Great Lakes coasts, as well as in Alaska, Hawaii, Puerto Rico, Guam, and the U.S. Virgin Islands.

- Established by enactments of state government, ports develop, manage, and promote the flow of waterborne commerce and act as catalysts for economic growth. These agencies include port authorities, special purpose navigation districts, bi-state authorities and departments of state, county, and municipal government.
- Public ports develop and maintain the terminal facilities for intermodal transfer of cargo between ships, barges,

trucks, and railroads. Ports build and maintain cruise terminals for the growing cruise passenger industry.
- In addition to maritime functions, port authority activities may also include airports, bridges, tunnels, commuter rail systems, inland river or shallow draft barge terminals, industrial parks, foreign trade zones, world trade centers, terminal or shortline railroads, shipyards, dredging, marinas and other public recreational facilities.
- Public ports also play a critical role in our national security, peace-keeping, and humanitarian efforts around the world. In particular, ports support the mobilization, deployment, and resupply of U.S. military forces.
- Ports on the coasts and inland waterways provide 3,214 berths for deep draft ships and transfer cargo and passengers through 1,941 public and private marine terminals."

The remaining ports in the United States are either privately run by commercial operators or managed by local municipalities.

Overall MTS is more managed than organized. The USCG and the U.S. Army Corps of Engineers are responsible for the safe operation of the MTS. The USCG has jurisdiction over vessels in U.S. waters and can order them to move or conduct specified actions deemed necessary for the safety of a port. All maritime and waterfront facilities are also under USCG jurisdiction in regard to safety and security. Additionally, local authorities may have some shared jurisdiction over marine and waterfront facilities.

The placement of maritime facilities, cruise ship operations, and marine services is driven by national and international economics and changes continually.

3.2.6 Operations

There are many ways to divide operations within the MTS. The most appropriate way for this project is to break it into six specific modes as follows:

- Scheduled liner trade,
- Bulk ship trade,
- Tug and barge trade,
- Passenger vessels and ferry boat trade,
- Cruise ship trade, and
- Recreational boating.

Scheduled liner trade consists primarily of intermodal container vessels that are 500 to 1,100 feet in length. They have crews of 12 to 30 and are mostly foreign flagged. Their schedules are set by their international corporate offices to maximize revenue. These vessels will seldom be in any one port for more than a day.

Bulk ship trade consists of ships designed to carry oil, chemicals in bulk, or dry products (e.g., grain, ore, or coal). These vessels generally operate in the tramp trade although some do have regularly scheduled routes. These ships may remain at anchor for considerable periods of time in a port after they have made their delivery and are waiting for another order.

Tug and barge trade is primarily conducted by U.S. flagged vessels. Barges today may be as large as ships (500 to 700 feet). They carry all forms of cargo. For coastal ports, their primary use is for the movement of oil and to a lesser extent intermodal containers. On the inland waterways they are moved in large numbers (6 to 48) lashed together. They are used to move oil, grain, ore, coal, and other dry bulk cargo. The inland barge trade is both scheduled and on demand. The oil trade on the coast is primarily on demand whereas the container barge trade is run on a schedule.

Passenger vessel (other than cruise ships) and ferry boat trade is primarily conducted by U.S. flagged vessels. Schedules are set for regional demand, many times varying by season. Ferry boat routes are generally short in length (less than 2 hours). Ferry boats are run by both private and public entities. Passenger vessels cater to sightseeing, dinner cruises, and ecotourism (e.g., whale watching), and their voyages are generally less than 8 hours long. Passenger vessels are usually run by private entities.

Cruise ship trade is primarily conducted by foreign vessels. These ships are home-ported in about a dozen U.S. ports and make port calls in a number of other ports. Most of these ships depart on the weekends for 3- to 14-day voyages and return to their homeport to begin the cycle again. Cruise ship schedules are published about a year in advance and are set to capture the planned market share of cruise ship customers.

Recreational boats are numerous, are owned and operated by the public, and range in size from small canoes to 100-plus-foot-long yachts.

All commercial vessels are under the control of a licensed mariner. Each such vessel is required to carry certain safety equipment. In addition certain waterfront facilities and most commercial vessels are being required to develop and implement security plans by an international convention (SOLAS ISPS) and national law (Maritime Transportation Security Act of 2002). These plans basically require that the vessels and terminals have reasonable security to prevent unauthorized personnel from gaining access and to ensure that contingency plans exist for specified events such as bomb threats and hostage situations.

3.2.7 Emergency Plans and Organization

In the event of a threat to the MTS, the USCG is responsible for managing its operation. The USCG's authority in responding to a threat to the MTS is found in 33 CFR 6-160 and includes the authority to control any vessel or waterfront facility, close off or restrict access to a waterway to anyone, and even order the destruction of a vessel. Each portion of the MTS is part of a USCG Captain of the Port (COTP) Zone. Each COTP has an area security committee formed to use the knowledge of all parts of the MTS from government to labor within a specified area having responsibility for an area security plan to deal with possible security threats. The area security plans explain how security threats will be managed and who will be in charge. The USCG is in charge initially; however federal emergency plans can shift that responsibility to other agencies in response to certain threats (e.g., weapons of mass destruction). When an incident or security threat materializes, these committees and their plans are used to rapidly disseminate information to those with a need to know.

In addition to the area security plans, each COTP maintains plans for managing natural disasters and regional emergencies. These plans are developed locally by the COTP and vary in complexity because of the perceived threat and availability of resources.

Implementation of the Maritime Transportation Security Act (MTSA) 2002, falls under the USCG, which, in 2003, published new security plans and security officer regulations in 33 CFR Parts 101 to 106. All vessels in waters under U.S. jurisdiction are subject to USCG Area Security Plans, as described in 33 CFR 103. Area Security Plans include vessel identification and navigation requirements. Further requirements vary with the area. Designation of vessel types for which more stringent national security regulations apply is based on determinations of relative risk, which includes both the likelihood of an event and the magnitude of the effects of an event. In general, depending on a vessel's gross weight, cargo types, and number of passengers, it may be required to conduct vulnerability assessments and to develop USCG-approved security plans that may include emergency response aspects such as passenger evacuation.

3.2.8 Historical Emergency Actions

During the terrorist attacks of September 11, 2001, ferry boats and other commercial vessels shuttled thousands of people from Manhattan to New Jersey, Long Island, and Staten Island. After 9/11, temporary ferry lines were established to allow commuters to get to work despite damage to certain railway systems (for example the PATH trains into lower Manhattan). Many large tugboats are equipped with firefighting monitors and often assist in suppressing maritime fires. All commercial vessels are equipped with VHF FM radios and are required to monitor certain channels for informational and emergency broadcasts. The maritime industry has a proud history of lending assistance during emergencies, including participating in search and rescue operations.

3.2.9 System Summary Matrix

Table 3-11 summarizes maritime operational sequences, traffic flow, and historical emergency response. Table 3-12 summarizes maritime control options, operational limits, and existing authority.

3.3 THE RAILWAY SYSTEM

3.3.1 Definitions

Freight rail statistics exclude passenger, commuter, and excursion railroads, subways and mass transit systems, and freight railroads that operate solely on behalf of an individual company and do not interchange traffic with other carriers. Miles of road is the aggregate length of railway excluding yard tracks and sidings and does not include parallel miles of road with two or more tracks. The miles of road operated total is greater than the mileage owned total because more than one railroad operates some railways through trackage rights. Miles of road owned can be calculated as the difference between miles of road operated and miles of road with trackage rights.

Railroad companies are classified into five groups:

- Class I. Railroads with an operating revenue of at least \$266.7 million in 2001. In 2002, the minimum revenue for this category was \$272 million. These carriers operate in many states, with most of their operations for long-haul, high-density intercity traffic. This class represents 1 percent of the number of U.S. freight railroads, 68 percent of the industry's operated mileage, 88 percent of the industry's employees, and 92 percent of the industry's freight revenues.
- Regional. Railroads with at least 350 route miles and/or revenue between \$40 million and the Class I minimum. Railroads in this class are linehaul, and typically operate 400 to 650 miles of road in a region located in two to four states.
- Local linehaul. Railroads that operate less than 350 miles of road and have annual revenues less than \$40 million. These carriers generally perform point-to-point transportation services over short distances. Most operate less than 50 miles of road and serve a single state.
- Switching and terminal (S&T). Railroads that primarily provide switching and/or terminal services, rather than point-to-point services. These carriers pick up and deliver cars between one or more connecting linehaul carriers within a specified area.
- Foreign-owned. Railroads owned by one of two Canadian companies: Canadian National Railway and Canadian Pacific Railway. Canadian company operations in the United States can be classified as any of the above four classifications. Inclusion of Canadian company U.S. operations in U.S. rail statistics varies depending on the reporting source. Tables 3-13 through 3-15 provide information on the relative size of U.S., Canadian, and Mexican rail operations in the United States.

TABLE 3-11 Maritime Operational Sequences, Traffic Flow, and Historical Emergency Response

Operational Sequences	Traffic Flow		Historical Emergency Response	
	Traffic Types	Traffic Patterns	Short Term (2 hr)	Long Term (>2 hr)
Passenger Vessels, Cruise Ships, and Ferry Boats: Operate nearly exclusively on present schedules. **Passengers or Cargo Accumulate:** At the marine terminal prior to the vessels arrival. Ferry boats experience high peak service during the weekdays in the morning and afternoon (rush hour).	**Normal:** A mix of workers, students, shoppers, tourists, and others on fixed routes, on or near schedule. Peak demand during the morning and evening hours, and during some events. **Constraining Emergencies:** Reduced or suspended service during severe weather emergencies (e.g., hurricane). **Expanding Emergencies:** Expand service during natural or manmade disasters (e.g., earthquake, terrorist attack, blackouts, flood).	**Routine:** To and from specified marine terminals. The difference between peak and off-peak is generally only the frequency of transits. **Emergency:** Vessels can be rerouted to any pier or waterfront with adequate draft for the vessel to operate assuming passengers can access the vessel.	**Stop Service:** At event sites, at suspicious sites, and as directed. **Reroute Service:** Around known emergency site, suspicious areas, danger zones **Suspend Fares:** During area evacuations to reduce traffic during spiked demand (special events). **Other Options:** Inform passengers of travel alternatives, discourage use, provide special service.	◆ **Reroute service** ◆ **Evacuate people** ◆ **Suspend fares** ◆ **Inform passengers** ◆ **Dedicate vessels to first responders** ◆ **Modify other vessels for passengers** ◆ **Rent vessels from outside region**

TABLE 3-12 Maritime Control Options, Operational Limits, and Existing Authority

Control Options		Operational Limits		Existing Authority
Short Term (2 hr)	**Long Term (>2 hr)**	**Short Term (2 hr)**	**Long Term (>2 hr)**	**Options**
◆ **Reroute Service** ◆ **Evacuate People** ◆ **Suspend Fares** ◆ **Inform Passengers** ◆ **Dedicate Vessels to FR** ◆ **Use other vessels to carry passengers**	**Same as short term and:** ◆ **Rent/Borrow vessels and operators** ◆ **Modify Vessels to carry passengers** ◆ **Help from Employers (staggered work hours),** ◆ **Media (inform public)** ◆ **State and Local Government (special exemption—waiver of hour restrictions on vessel operators)**	**Stop or Reroute Service**—limited choices **Suspend Fares**—overcrowding **Add/Refocus Service**—lack of resources **First Responder Help**—different: command structure, culture, operations **Media Assistance**—inadequate coordination, coverage, frequency, etc. **Evacuate Vessels and Terminals**—lead time	**Same as short term and:** **Borrow/rent Vessels/operators**—lack of funding, stock, operators **Receive Assigned Assistance**—lack of resources, commitment, experience **Modify Vessels**—resources, time **Employers, Media, State and Local Government**—lack of control, not uniformly applied, etc. **Fuel Access**—may be limited due to delayed or suspended shipments.	**Stop/Reroute Service**—federal, local, and state government. **Suspend Fares**—local and state government. **Add/Refocus Service**—local and state government. **Substitute Service**—local, state, and federal government. **First Responder Help**—first responder organization, local and state government. **Media Assistance**—industry **Borrow/Rent Vessels/operators**—local, state, and federal government **Modify Vessels**—local, state, and federal government. **Employer Assistance**—industry **Special Exemption**—local and state government **Evacuate**—first responder organization, local and state government.

TABLE 3-13 Freight Railroad Industry Number of Companies, Miles Operated, Employees, and Revenue, 2001

Type of Railroad	Number	Miles Operated*	Employees	Freight Revenue ($ billions)
Class I	8	97,631	162,155	$33.53
Regional	34	17,439	10,302	$1.58
Local linehaul	314	20,881	5,023	$0.88
S&T	215	6,682	6,889	$0.59
Canadian**	2	728	N/A	N/A
Total	573	143,361	184,369	$36.58

(Source: American Association of Railroads (AAR))

* excludes trackage rights ** CN and CP operations that are not part of Class I

TABLE 3-14 Freight Cars in Service in North America, 2002

County of Owner		Relations		Car Co. and Shippers
	Total	Class 1	Other	
Canada	185,296	137,906	15,089	32,301
Mexico	33,969	19,823	6,335	7,811
U.S.	1,299,670	477,751	130,590	691,329
Total	1,518,935	635,480	152,014	731,441

(Source: AAR)

TABLE 3-15 Major North American Railroads Based on Revenue, 2001

Railroad	Country of Ownership	Revenue (million $)	% of Total Revenue
Union Pacific Railroad	United States	10,614	26%
The Burlington Northern and Santa Fe Railway	United States	9,201	23%
CSX Transportation	United States	6,454	16%
Norfolk Southern	United States	6,170	15%
Canadian National Railway	Canada	3,650	9%
Canadian Pacific Railway	Canada	2,386	6%
TFM (a subsidiary of Grupo Transportacion Ferroviario Mexicano)	Mexico	668	2%
FXE (a subsidiary of Grupo Ferroviario Mexicano)	Mexico	567	1%
Kansas City Southern Railway	United States	566	1%
Total		40,276	100%

(Source: AAR)

3.3.2 System Size

Freight railroads move 42 percent of U.S. domestic freight as measured in ton-miles, in addition to contributing billions of dollars each year to the economy through investments, wages, purchases, and taxes.

3.3.3 System Use

Coal is the single most important commodity carried by rail. In 2001, 46 percent of the tonnage and 23 percent of the revenue of Class I railroads was from coal transport. The primary use of coal is for the generation of electricity at coal-fired power plants, which produce more than one-half of the nation’s electricity. Approximately two-thirds of the coal used for generating electricity is shipped by rail. In 2001, 70 percent of the coal shipped by rail originated in three states: Wyoming, West Virginia, and Kentucky. The top five states for termination of coal shipments (i.e., Illinois, Missouri, Texas, Virginia, and Ohio), represent about 36 percent of coal shipments.

Intermodal traffic (i.e., truck trailers and containers transported by rail and at least one other mode of transportation) is considered a category of its own and represents about 20 percent of rail revenue. This growing category may soon exceed coal in terms of rail revenue. Other major commodities carried by rail are chemicals, including those used for public water purification; plastic resins; fertilizers; grain and other agricultural products; food; nonmetallic minerals, including phosphate rock, sand, and crushed stone and gravel; forest products, including lumber and paper; motor vehicles and vehicle parts; and waste and scrap materials, including scrap iron and paper. Table 3-16 presents rail tons originated and gross revenue by commodity group.

TABLE 3-16 Type of Freight Carried in 2002

Commodity Group	Tons Originated		Gross Revenue	
	(000)	% of total	(million)	% of total
Coal	785,006	44.4	$7,797	21.2
Chemical and allied products	158,734	9	$4,707	12.8
Farm products	137,717	7.8	$2,711	7.4
Nonmetallic minerals	125,643	7.1	$967	2.6
Food and kindred products	102,230	5.8	$2,657	7.2
Miscellaneous mixed shipments*	97,228	5.5	$4,900	13.3
Metals and products	55,905	3.2	$1,350	3.7
Stone, clay, and glass products	49,279	2.8	$1,149	3.1
Lumber and wood products	47,533	2.7	$1,628	4.4
Petroleum and coke	40,207	2.3	$977	2.7
Waste and scrap materials	39,440	2.2	$717	2
Pulp, paper, and allied products	37,212	2.1	$1,567	4.3
Motor vehicles and equipment	35,902	2	$3,626	9.9
Metallic ores	31,376	1.8	$285	0.8
All other commodities	23,258	1.3	$1,704	4.6
Total	1,766,671	100	$36,742	100

(Source: AAR)

* Miscellaneous shipments are primarily intermodal. Some intermodal shipments are included in the commodity-specific categories.

In addition to commercial shipments, railroads provide critical support to the Department of Defense (DOD) Strategic Rail Corridor Network (STRACNET), which includes more than 30,000 miles of rail line and provides the backbone for the movement of DOD shipments. DOD shipments, in addition to some commodities, such as certain chemicals and munitions, present greater risk of terrorist acts or accidental spillage. The rail industry has assessed these vulnerabilities and taken steps to minimize these risks, as addressed in the Emergency Plans and Organization section, below.

From a geographical use perspective, the 10 states with the greatest number of rail miles represent 40 percent of the national total rail miles. These states are listed in Table 3-17. The top 10 states for rail tons originated and for rail tons terminated are shown in Tables 3-18 and 3-19, respectively.

3.3.4 Financing and Ownership

More than 90 percent of U.S. freight railroads, including all Class I carriers and all but one regional railroad, are privately owned and operated. Most railway track in the United States is owned by these private companies, which construct, maintain, and pay property taxes on their road and facilities. With respect to capital intensity, freight railroads are near the top of all major U.S. industries. From 1980 to 2001, 45 percent of their operating revenue was spent on capital expenses and

TABLE 3-17 Top 10 States for Rail Miles, 2001

State	Rail Miles	% U.S. Total
Texas	10,473	7.3%
Illinois	7,197	5.0%
California	6,052	4.2%
Ohio	5,484	3.8%
Pennsylvania	5,145	3.6%
Kansas	5,084	3.5%
Georgia	4,795	3.3%
Minnesota	4,504	3.1%
Indiana	4,185	2.9%
Missouri	4,168	2.9%
Top 10 Total	57,087	39.8%
U.S. Total	143,361	100%

(Source: AAR)

TABLE 3-18 Top 10 States for Rail Tons Originated, 2001

State	Rail Tons Originated	% U.S. Total
Wyoming	375,510,739	20%
West Virginia	127,283,023	7%
Illinois	119,524,605	6%
Kentucky	109,670,324	6%
Texas	108,589,349	6%
Minnesota	74,389,180	4%
Florida	64,413,774	3%
Ohio	61,036,161	3%
Pennsylvania	59,815,765	3%
California	57,609,683	3%
Top 10 Total	1,157,842,603	61%
U.S. Total	1,898,840,100	100%

(Source: AAR)

TABLE 3-19 Top 10 States for Rail Tons Terminated, 2001

State	Rail Tons Terminated	% U.S. Total
Texas	189,633,233	10%
Illinois	186,302,393	10%
Ohio	97,329,450	5%
Florida	93,820,901	5%
California	92,684,031	5%
Georgia	83,033,699	4%
Missouri	78,030,320	4%
Wisconsin	70,169,618	4%
Virginia	68,915,424	4%
Indiana	63,407,891	3%
Top 10 Total	1,023,326,960	53%
U.S. Total	1,942,330,529	100%

(Source: AAR)

equipment and infrastructure maintenance. For long distances, rail is generally the cheapest form of freight transportation in the United States; the trucking industry is its biggest competitor. To maintain its niche in the U.S. transportation marketplace, railroads have consistently been within the lowest quartile of all U.S. industries in terms of profitability.

Revenue by carrier type for 2001 is shown in Table 3-13, above. Class I carrier financial statistics, including operating revenue and expenses, net income, and return on average equity in 2002, are shown in Table 3-20 below. Class I carrier operating statistics, including freight revenue per ton-mile in 2002, is shown in Table 3-21.

3.3.5 General Organization

All Class I railroads are owned by private corporations, as are most regional railroads. Each corporation is run by a board of directors that appoints a chief executive officer to oversee railroad management. Most major U.S. cities are served by more than one Class I railroad; secondary cities may be served by only one Class I carrier and/or by smaller regional railroads. The Class I railroads have areas of general geographical concentration. For example, transport between the West and Midwest is primarily provided by Burlington Northern and Santa Fe Railroad (BNSF) and Union Pacific (UP); transport between the Midwest, East, and South is largely provided by Norfolk Southern and CSX. No single railroad owns railway from the West to the East, but rail company partnerships facilitate coast-to-coast transportation, as well as international transportation to Canada and Mexico.

TABLE 3-20 Financial Statistics of Class I Railroads, 2002

Freight revenue (billion)	$34.1
Operating revenue (billion)	$35.3
Operating expense (billion)	$29.6
Net income (billion)	$3.2
Operating ratio	84%
Return on average equity	8%

(Source: AAR)

TABLE 3-21 Operating Statistics of Class I Railroads, 2002

Freight revenue per ton-mile	$0.0226
Average tons per carload	63.3
Average tons per train	3,030
Average length of haul (miles)	853

(Source: AAR)

Although U.S. railroads have always been privately owned, the extent of government regulation over them has varied as the economy and modes of transportation have changed. The Staggers Rail Act of 1980 reduced government regulation of railroads to allow them to establish their own routes, adjust rates and services to market conditions, and differentiate rates based on demand. The Interstate Commerce Commission (ICC) retains authority over some non-rate areas and can set maximum rates or take certain other actions if a railroad is found to have abused its market power or engaged in anticompetitive behavior.

Before the Staggers Act, the Rail Passenger Service Act of 1970 allowed the private rail industry to exit the intercity passenger rail market, which was consistently operating at a loss. The same act established government-owned Amtrak, which has remained the sole intercity passenger rail carrier in the continental United States. Amtrak owns approximately 750 miles of railroad. The remaining miles over which it operates are owned by freight railroads, which it pays for track use. A few dozen cities in the United States have commuter and light rail passenger service between a central city and its suburbs or outlying region. These services are owned by either private companies or local and state governments. Some of these commuter passenger operators own all or part of the railway over which they operate; however, it is becoming increasingly common for commuter passenger operators to extend their operations using railroad right-of-way purchased from freight railroads. In some cases, a freight railroad has been contracted to provide passenger service (e.g., Union Pacific in the Chicago area), but in general, freight railroads limit their operations to freight.

The Association of American Railroads (AAR) provides a unified voice and point of organization for the rail industry with respect to regulations, safety, and more recently, security and associated coordination with federal and local authorities. AAR membership includes all major freight railroads in the United States, Canada, and Mexico, as well as Amtrak, and represents more than 96 percent of intercity freight rail service and essentially 100% of intercity passenger rail service.

The FRA enforces rail safety regulations and conducts research and development in support of improved safety and rail policy. The primary research center for the North American railroad industry is owned by the FRA and operated by the Transportation Technology Center, Inc (TTCI), a subsidiary of the AAR. The facility is for both freight and passenger railroads, with a focus on safety, reliability, and productivity. In addition to test track, it operates a training center for emergency personnel responding to transportation accidents involving hazardous materials.

3.3.6 Operations

Railroad freight runs on closed guideways largely controlled by train dispatchers. The dispatchers direct locomotive engineers on direction and speed. Cargo waybills (i.e., agreements to haul) are largely electronic, allowing each shipment to be easily tracked by its listed content and location. Encrypted data are used to transfer information on shipments that are critical from a security perspective. Hazardous materials and munitions shipments, regardless of mode of transport, are governed by separate federal regulations that require compliance with safety-related standards and carrying a manifest of hazardous cargo. All rail cars and containers passed between different companies (i.e., most shipments) are required to have two radio frequency identification tags that allow electronic identification of the car's history, ownership, and contents. Thus, while personnel picking up and transporting cars or containers may not know the cargo contents, information on a particular car can be readily obtained when needed. After a car enters a railroad yard, its location is directed and tracked by the yardmaster. Overall, unlike other freight transportation modes, the rail industry can relatively easily provide information on the locations of all its shipments and cars through a single point (i.e., American Association of Railroads and its subsidiary, Railinc, which maintains an extensive databases on rail activities). Although some smaller railroads are not part of AAR, these railroads typically transfer cars/containers to and from AAR members, along with origin and destination information, enabling good estimations of car locations. GPS technology has been installed on some locomotives and rail cars (particularly those carrying frozen goods) for more precise locations. Tracking the location of a shipment does not ensure that the contents have remained unchanged.

Recently implemented rules require land freight transporters to notify U.S. Customs of cargo contents at least 4 hours before crossing national borders. In contrast, ocean transporters must provide cargo contents lists at least 24 hours before port arrival. Shipping containers and freight cars may be initially inspected (x-rayed) at receiving ports. An electronic targeting system scores all cars that enter the United States based on their ownership and contents and so forth and identifies those to receive intensified inspections. Lower scores (i.e., less critical security threats) are given to Customs-Trade Partnership Against Terrorism (CTPAT) members, who have previously provided the U.S. Bureau of Customs with extensive company and shipment information.

Rapid decision-making in response to emergencies has always been part of the rail system for dealing with more common emergencies such as natural disasters (e.g., drought and snowstorms). Rapid decisions regarding emergency changes in security and operations are typically made at a high (i.e., CEO) level. Rotating round-the-clock shifts of top decision-makers are typically employed so that emergency decisions can always be made quickly.

3.3.7 Emergency Plans and Organization

Shortly after the terrorist attacks of September 11, 2001, the railroad industry established the Railroad Security Task Force through the AAR. The task force included 150 railroad industry representatives and former government security and intelligence personnel and sought to develop a comprehensive risk analysis and security plan based on CIA and national intelligence community best practices. The resulting plan addresses hazardous materials, operations, infrastructure, information technology and communications, and military movements in the railroad system. This plan uses a database created to prioritize railroad assets, assess railroad vulnerabilities and terrorism threats, calculate risks, and identify risk-reduction countermeasures. Alert levels and actions to be taken at each level have been defined and the role of the AAR operations center and railroad alert network has been delineated.

Railroad Security Task Force findings have led to an increase in employee security awareness and training, and employee records have been compared with FBI terrorist lists. There have also been increases in the tracking and inspection of hazmat and munitions movements; security of railroad physical assets; random inspections; spot identification checks; cybersecurity procedures; coordination with Military Transportation Management Command; and the use of encryption technology for selected data communications.

Based on task force recommendations, the rail industry has developed plans for immediate response to any threats in the transportation network. Furthermore, a round-the-clock operations center has been established at the AAR to coordinate industry-wide rail freight security. The AAR alert network operates from an industrial security clearance room, allowing constant and secured communications between federal authorities and railroad companies. In the event of a terrorist threat, the AAR alert network would communicate with all Class I carriers in the United States and Canada and with many regional carriers.

The rail industry has conducted war game exercises to further identify potential problems. These exercises may help authorities delineate circumstances under which it is better to keep traffic moving rather than halting it and providing a standing target, recognize the domino effects of late or cancelled shipments (e.g., chemicals to maintain drinking water sanitation), and assess capabilities for population evacuations with boxcars. The Railroad Security Task Force vulnerability assessment includes relative assessments of attack effectiveness on tunnels, bridges, track, and shipments. Concerns with shipment attacks may include theft of shipments for illegal sale or use, releases and explosions of hazardous cargo (e.g., chemicals or munitions), and contamination or poisoning of food shipments. This vulnerability assessment information is considered highly sensitive, along with the steps implemented at each alert level and thus these details are not presented in this report.

3.3.8 Historical Emergency Actions

Immediately after the terrorist attacks of September 11, 2001, the railroad industry worked closely with local, state, and federal authorities to increase inspections and patrols, often with its own police forces. Freight traffic in the New York area was briefly suspended and, throughout the country, access to key facilities was restricted and operational practices were modified as antiterrorist measures. As cleanup efforts of the September 11 attacks began, gondola cars were donated to assist with hauling debris. Other types of assistance the rail industry has provided during emergencies include hauling needed supplies free of charge and increasing on-duty staff to meet emergency shipment needs.

At the start of U.S. military action in Afghanistan, in consultation with federal security agencies, the railroad industry maintained a 72-hour “Red Alert” status, with associated additional security protocols. Shipments of hazardous materials were suspended during this alert, which provided experience with the repercussions of shipment delays. AAR coordination with the Chlorine Institute, the American Chemistry Council, and the Fertilizer Institute has greatly increased in recent years to improve both security and emergency planning. Overall, since the terrorist attacks of September 11, the rail industry has made great strides to improve freight security and emergency planning in excess of government requirements. Historically, the rail industry has provided great assistance during emergencies. The industry’s financial stability and related well-maintained infrastructure facilitates this assistance.

Historical rail accidents have been studied and considered in the rail industry emergency plans. For example, in July 2001, a railroad accident inside the Howard Street tunnel in Baltimore caused chemical tank cars and cars loaded with paper products to burn for 3 days. The accident was studied by the Nuclear Regulatory Commission (NRC) as a worst-case model of the type of accident that could befall a shipment or nuclear waste by railroad. The conclusions were that nuclear waste containers would have survived the fire, but these results have become highly controversial. This case is an example of the type of situation (whether involving deliberate attack or of accidental origin) that could occur, whether nuclear materials are involved or not. The evacuation requirements and response needs for such an accident (nuclear or chemical) have been and are being considered by the rail industry.

Another instructional historical rail accident occurred in 1979 near the town of Mississauga, Ontario. A railroad car undercarriage failure caused a propane tank explosion followed by ruptures of cars containing chlorine and other chemicals, resulting in an extremely hot and acrid fire. More than 210,000 residents were evacuated from the area. This accident is a model of the type of situation that can result when trains contain a mix of different types of cargo (as they typically do). Some types of cargo can seriously diminish the ability to respond. In this case, the presence of chlorine gas prevented fire fighting personnel from being able to respond for a significant amount of time.

3.3.9 System Summary Matrix

Table 3-22 summarizes railway operational sequences, traffic flow, and historical emergency responses. Table 3-23 summarizes railway control options, operational limits, and existing authorities.

3.4 THE AVIATION SYSTEM

3.4.1 Definitions

The aviation industry comprises aircraft; their operators; the people and goods transported; airports and supporting infrastructure; and the communications, navigation, and control infrastructures that make reliable air transportation possible. The aviation industry consists of several major sectors, or categories of operations, that have distinctly different roles in a threat environment. These sectors are

- Air carriers, which transport people;
- Cargo carriers, which include air carriers in addition to freight airlines;
- The business use sector, which includes operators such as mining companies, power transmission companies, and oil exploration, charter aircraft, and individuals operating aircraft for business purposes;
- The agricultural use sector (dusting and spraying); this sector is a sub-sector of business aircraft;
- The corporate transport sector, which includes many minor and major corporate fleets operated to transport employees;
- The air taxi industry (transport on demand), which is quite large and diverse;
- The public use sector, which includes Emergency Medical Services (EMS) operations, forest service and forest fire suppression, law enforcement, and the USCG air fleet; and
- The pleasure flying sector.

(*text continues on page 54*)

TABLE 3-22 Railway Operational Sequences, Traffic Flow, and Historical Emergency Response

Operational Sequences	Traffic Flow		Historical Emergency Response	
	Traffic Types	Traffic Patterns	Short Term (2 hr)	Long Term (>2 hr)
Freight: Privately owned railway, locomotives, and freight cars. Shipments are tracked from the agreement to ship until delivery. **Passenger:** Intercity passenger travel exclusively by Amtrak (federally owned), commuter, and within-city passenger transport addressed under Mass Transit.	**Normal:** Mix of many cargo types, typically for longer distance transport; some hazardous materials and munitions. **Constraining Emergencies:** Traffic may be reduced during severe weather (e.g., snow, hurricane). Traffic has been halted for up to 72 hours under high-level security alerts. **Expanding Emergencies:** Delivery of emergency supplies and use for evacuations.	**Normal Operations:** Rail traffic greatest in larger cities. **Emergencies:** Deliveries of emergency supplies and provision of boxcars for evacuations.	**Suspend Transport:** A 72-hour suspension was applied when the U.S. invasion of Afghanistan began. **Reroute/Delay Deliveries:** Deliveries to the New York area were briefly halted as a result of the 9/11 terrorist attacks.	Same as short term and: ◆ Repair/ construct railway ◆ Increase deliveries to area in need ◆ Dedicate equipment to emergency assistance ◆ **Emergency Deliveries:** Transported hay without charge during droughts, donated gondola cars for 9/11 debris removal.

TABLE 3-23 Railway Control Options, Operational Limits, and Existing Authority

Control Options		Operational Limits		Existing Authority
Short Term (2 hr)	**Long Term (>2 hr)**	**Short Term (2 hr)**	**Long Term (>2 hr)**	**Options**
Suspend Transport: apply to all or selected freight. **Reroute/Delay Deliveries:** halt deliveries to emergency areas. **Emergency Deliveries:** deliver emergency supplies.	**Same as short term and:** ◆ **Repair/construct railway** ◆ **Increase deliveries to area in need** ◆ **Dedicate equipment to emergency assistance**	**Suspend Transport**—public health dangers with suspensions of 3+ days for water treatment shipments; stationary hazardous cargo may be an easier target. **Reroute/Delay Deliveries**—deliveries essential for public health may be critically delayed. **Emergency Deliveries**—limited by rail track location, equipment, personnel.	**Same as short term and:** **Repair/construct railway**—financing, need land ownership for new construction. **Increase deliveries to area in need**—equipment and personnel limits. **Dedicate emergency equipment**—equipment limits **Fuel Access**—reduced or suspended deliveries of fuel may limit operations.	**Suspend Transport**—industry **Reroute/Delay deliveries**—industry **Emergency deliveries**—industry **Repair/construct railway**—industry, local and state government **Increase deliveries to area in need**—industry **Dedicate equipment to emergency assistance**—industry

In a broad sense, operations for hire, such as airline, cargo, and air taxi, are classified as commercial aviation, while private operations for business, corporate, pleasure, and public use are classified as general aviation (GA). The final sector (not to be treated here) is domestic military aviation operations.

3.4.2 System Size

The air carrier industry includes 87 different airline companies, of which 15 are considered major. Cargo carriage is an important revenue source for the air carriers and is the sole means of support for many relatively unknown freight operators as well as the well-known express companies, each of which operates major 'airlines' themselves. The next largest sectors (in terms of dollars expended) are the business use and corporate transport categories. The business use sector includes the agricultural aircraft sector (dusting and spraying), which is small economically, but very important from a threat viewpoint. The corporate transport category involves many minor and major corporate fleets operated for employee transport. The air taxi industry (transport on demand) is large and diverse. The pleasure flying sector is economically important and encompasses more than 160,000 aircraft of many varieties, a large pilot population, and relative ease of entry, all of which present a vast opportunity for mischief. Table 3-24 quantifies the relative magnitudes of these several sectors.

3.4.3 System Use

The U.S. aviation industry transports both people and freight. In 2002, 595 million passengers enplaned, representing 32.77 billion revenue passenger-miles. In 2001, air freight represented 5% of total U.S. intercity freight revenue, but less than 0.05% of national freight tons and ton-miles. Freight transport provides a significant revenue source for all major airlines, and several large airlines exclusively provide freight service.

3.4.4 Financing and Ownership

The air transportation system can be thought of as consisting of three segments: the airports; the communications, navigation, and ATC system; and the aircraft. Ownership and operation of each segment is distinct. The airports typically are owned and operated by municipalities or counties or by state-chartered authorities. The communications, navigation, and ATC system facilities are owned almost exclusively (with exceptions, such as the Contract Tower Program) by the federal government. The noteworthy exception is the ARINC (Aeronautical Radio Inc.) communications network, which is owned by the airlines. The government is also responsible for promulgating regulations and certifying pilots. Commercial operators and private owners own the aircraft.

3.4.5 General Organization

Besides aircraft and the people who operate and maintain them, other entities compose the air transportation system:

- Airports—Airports include major, intermediate, and minor hub airports; the non-hub commercial airports; public-use GA airports and heliports; private airports and heliports; and military airports. The GA airports can be roughly divided into a group primarily serving business and corporate operators and a group primarily serving

TABLE 3-24 Size and Economic Characterization of the Aviation Industry

Sector	Number of Aircraft	Employees/ Operators	Vehicle Miles	Passengers/ Tons	Passenger Miles/Ton Miles (annual)	Economics	Fuel Consumption (annual)
Air Carrier	8,055	642,797 employees	5,664M	595M passengers	516,129M passenger miles	$104.4B	14,845M gallons (jet)
Air Cargo				20M tons	58,400M ton-miles	$ 8.2B	
Air Taxi	4,019	22,000 pilots					
General Aviation (total)	217,533	637,000 jobs (direct and indirect) 600,000 pilots	>3,877M	180M passengers	>13,500M passenger miles	$ 17.5B (direct) $102B (direct and indirect)	337M gallons (jet) 998M gallons (gas)
Corporate	11,033						
Business	25,169						
Agriculture	4,294						
Pleasure	163,000						
Other	14,037 (incl. air taxi)						

(Source: USDOT National Transportation Statistics, 2002, and "Report of the Aviation Security Advisory Committee Working Group on General Aviation Airports Security", National Association of State Aviation Officials (NASAO), Oct 1, 2003.)

hobbyists. Private airports and heliports are built and used in many cases by business and public-use operators such as EMS. Military airfields are mentioned for their obvious function and because they can serve as medical evacuation destinations (particularly for quarantine purposes).

- Communications and Navigation—Communications facilities, both public and private, are the backbone of aviation. Communications are essential in both controlled and uncontrolled environments. In contrast to most other forms of transportation, the robust aircraft communications environment (which is immune to short-term power failures) allows rapid response to changing conditions and emergencies (witness the rapid grounding of the entire commercial air fleet on September 11, 2001). This capability can serve to eliminate general (or nonspecific) threats, avoid regional threats, or respond to supply or evacuation requests. The navigation and landing system (much of which is also immune to power outages) is used by virtually all operators, even visual flight rules (VFR) operators. Operations by instrument flight rules (IFR) operators can continue in low-visibility conditions regardless of the cause of the reduced visibility.
- Air Traffic Control (ATC)—The ATC system, operated exclusively by the federal government (and military), guarantees separation of IFR aircraft from other aircraft and facilitates separation of almost all aircraft. It provides the planning and sequencing services that ensure the efficient overall operation of the system. The ATC system is fundamentally configured as a pyramid. The System Command Center at the top originates the basic strategy to control flow and to minimize delays and weather impacts. The twenty Air Route Traffic Control Centers (ARTCCs) in the middle control the en route operation of aircraft and ingress/egress to uncontrolled airfields. Finally, the many Terminal Radar Control (TRACON) Facilities, control towers, and flight service stations at the bottom control landings and takeoffs and handle flight plan filings.

3.4.6 Operations

A fundamental characteristic of the air transportation industry is that, with the exception of medical evacuation, air transportation is *always* multi-modal. This applies to cargo as well as people (and contrasts with automobile and truck transportation, which is unimodal).

Private users of aviation operate in an “anytime, anywhere” environment and typically fly as directly as possible from origin to destination. The air carrier system has evolved to what is known as the “hub and spoke” system, with each airline concentrating operations at one or more hub airports. This is extremely important from the threat viewpoint. The hub can be used to disperse contaminants widely via the spokes. It, however, has little effect on air transport in the emergency response mode. Hub and spoke can be abandoned at any time in favor of the anytime, anywhere concept, either to disperse evacuees or to concentrate delivery of supplies and relief workers.

Commercial air operations are tightly managed and controlled (by the ATC system and company dispatch offices). The result is a system that can respond immediately to critical stimuli. Planning and control are critically important in the evacuation mode. Air operations (unlike automobile evacuation) require staging of empty aircraft into the region to be evacuated. Unlike ground environments, where inbound lanes can be switched to double outbound capacity, the departure capacity of an airport cannot typically be increased.

Weather disruptions to air travel result from major storm systems redirecting en route progress and slowing or preventing operations to major airports. Such a situation can diminish the ability of aircraft to respond to emergency situations. These situations serve as valuable models for studying the effects of attacks that result in closure of one or more airports.

The airline and airport infrastructure is sufficiently robust to supply fuel and flight crews for intensive relief operations over an extended period of time (possibly 2 weeks) without re-supply. General aviation airports also typically store substantial quantities of fuel relative to the size of their operation.

With respect to industry management, the pyramidal structure of the ATC system and its independent power supplies and communications channels, the highly-organized nature of airline (and corporate) flight dispatch offices, and the ARINC communications network provide for a very highly structured management and control system. Each aircraft is capable of virtually autonomous operation even in low visibility conditions (assuming that the GPS network is operational, although it is substantially true even if GPS is not operational). All that is required from the ground environment are separation services. Tight control over aircraft operations enables them to respond as directed.

3.4.7 Emergency Plans and Organization

Capabilities and Limitations of Air Transportation

A very important capability lies in the use of helicopters to provide first-responder and evacuation services and surveillance of a disaster scene to coordinate activities of ground personnel. The limitations are that only a few such helicopters are properly equipped and staffed in any given area, severely limiting the scale of services that can be provided. Inasmuch as most of the population of the United States lies reasonably close to the oceans and inland seaways patrolled by the USCG, the USCG helicopter fleet, fundamentally designed for search and rescue operations, is a significant adjunct to local capabilities. National Guard and Army helicopters are important for evacuation operations.

A serious limitation on the ability to respond in a local disaster environment stems from the fragmented jurisdictions of the various involved organizations. Even local law enforcement agencies in many metropolitan areas are not able to cross-communicate because of differences in radio systems. Local law enforcement agencies, medical centers, private EMS operators, the USCG, and available military responders are all under separate jurisdictions. The need for prior planning and organization is obvious. The FAA has published two Advisory Circulars that apply directly:

- AC 00-7D, State and Regional Disaster Airlift (SARDA) Planning (09/15/98) and
- AC 00-59, Integrating Helicopter and Tiltrotor Assets into Disaster Relief Planning (11/13/98).

These provide guidance for the use of all GA resources, EMS airlift, and so forth, for disaster recovery. State and local planners should likewise be aware of other organizations that may exist in the local area. These include the Civil Air Patrol (organized under the auspices of the Air Force), the Emergency Volunteer Air Corp (EVAC), the Air Care Alliance, Angel Fights, and any other local GA clubs and organizations. Coordination by local disaster relief officials with the SARDA plan (if present), law enforcement, volunteer organizations, and local airport management will be required in order for effective disaster response to be available.

SARDA resources may include aircraft and other resources under the control of state and local governments, the National Guard, the DOD, and the USCG, as well as commercial operators, private aircraft owners, corporations, airfield operators, the Civil Air Patrol, and other volunteer organizations. The National Response Plan (NRP), published in 2004, can be activated in the event of a disaster. In that event, the states executing SARDA plans will then coordinate missions closely with Federal personnel as directed in the NRP.

Transport aircraft, in both passenger and cargo configurations, are extremely useful for bringing in responders and materials and evacuating the injured and the general populace. The major limitation is not the supply of aircraft available, but the ability to squeeze operations through limited airport capacity. The command and control capabilities available can result in a well-managed, efficient process. Many of the air carrier companies are participants in the Civil Reserve Air Fleet (CRAF). CRAF is made up of air carriers who commit under contract to provide operating and support personnel for DOD so that it can quickly mobilize the nation's airlift resources. CRAF response plans consider the need to move injured persons as well as cargo and personnel. Although CRAF was originally designed to meet DOD force projection requirements in a military emergency (troop and materiel transport), it can be exercised in response to any suitable national emergency that has been declared by the President or Congress.

Air Transportation Vulnerabilities

Much of the security effort being expended today regards hijack and sabotage prevention. The vastness and complexity of the air transportation system causes many additional vulnerabilities.

Commercial airports involve concentrations of people within the terminal buildings and in people-mover systems. Current precautions involve stepped up inspections of vehicles as they enter parking structures that are under, over, or next to populated buildings. Commercial airports also have large fuel tank farms, often totally aboveground, that are vulnerable to attack (particularly from the air). Even smaller general aviation airports have tank farms of sufficient size to present a tempting target.

The availability and potential use of shoulder-fired missiles designed to down aircraft is a very serious threat. Man Portable Air Defense Systems (MANPADS) include the well-known Russian SA-7, French Mistral, and U.S. Stinger missiles. An estimated 500,000 MANPADS exist and many are available on the black market. It is very difficult for a transport aircraft to detect such a missile, let alone take the required evasive action should one be detected. Airliners are not currently equipped with detection and spoofing systems such as those used on several types of military aircraft. The airline companies, which are in serious economic conditions, are loathe to expend funds on such systems. Cost estimates for equipping the domestic airline fleet range from $5 to $25 billion dollars.

General aviation airports are by their nature relatively vulnerable to sabotage. In many cases, few obstructions to entry (e.g., fences) are present, and access to airport property is unrestricted. Aircraft are relatively easy to steal and the airspace around the airport is uncontrolled, allowing perpetrators to make off with an aircraft undetected. It is not difficult to envision a motivated person (even if poorly trained in piloting small aircraft), already committed to suicide, attempting to steal and fly off in an aircraft.

Such bravado is not even required if a person is licensed and checked-out in an available type of rental aircraft. Aircraft rentals are commonplace. A licensed pilot could rent an aircraft, fly it to a remote airfield (or a pasture); load chemical, biological, or radiological materiel; and fly the aircraft off to the intended target.

Agricultural aircraft are used not only for spraying and dusting crops, but also for tasks such as mosquito suppression in urban areas. Two of the 9/11 hijackers were known to have investigated such aircraft for use as a weapon. Fortunately, there is little opportunity to rent such aircraft. Because crop dusting requires specialized training and experience, an inexperienced pilot would be unlikely to be hired as an agricultural pilot. Theft, however, is a possibility.

3.4.8 Historical Emergency Actions

The standard tight control of aircraft operations allowed the skies to be cleared of IFR traffic (which includes all commercial flights) in a matter of minutes after the terrorist attacks of September 11th. Another good example is the recent power failure affecting Ohio, Michigan, southern Canada, and the northeastern states. During the power outage, most flights already in the air were able to reach their intended destinations. Others were able to proceed safely to an alternate airport. As time progressed, departing flights were cancelled in many cases as a prudent response to the situation. Had an emergency evacuation been required, operations could have proceeded.

There have been several troubling experiences with infectious diseases recently, including the SARS breakout and the appearance of monkeypox in the United States. Air transportation was unfortunately directly involved in the global spread of SARS. Although monkeypox did not come to the United States by air; contaminated animals were imported from Ghana, distributed, and infected prairie dogs in pet stores, which in turn infected humans. New infectious diseases can be introduced with relative ease, and aircraft ventilation systems could be deliberately contaminated in an effort to start an epidemic.

Regarding response capabilities during hurricanes, airports are slow to snap back from wind and storm damage. There tends to be a large amount of debris to be cleaned up resulting from wind-damaged vehicles and aircraft. Even minor debris accumulations must be completely cleaned up to prevent the ingestion of foreign materials by jet engine intakes. This can result in closure of the airport for a day or two after the storm passes.

Flooding conditions often result in situations where the local populace (and sometimes relief workers) can become trapped and require evacuation, either by boat or by helicopter. Also, helicopters are ideal for searching and seeking out individuals in distress. Examples abound where helicopters have been pressed into service in rescue situations. For example, in the aftermath of the 1982 Air Florida crash into the Potomac on departure from Washington National Airport on a snowy day, a National Park Service helicopter was involved in the rescue activities.

3.4.9 System Summary Matrix

Table 3-25 summarizes aviation operational sequences, traffic flow, and historical emergency response. Table 3-26 summarizes aviation control options, operational limits, and existing authority.

Aviation Information Sources

National Transportation Statistics, 2002, Bureau of Transportation Statistics, U. S. Department of Transportation, BTS02-08.

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AC 00-7D, "State and Regional Disaster Airlift (SARDA) Planning (09/15/98)," ADA-20, Federal Aviation Administration, U.S. Department of Transportation.

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National Response Plan, Department of Homeland Security, December, 2004 (available at http://www.dhs.gov/dhspublic/interapp/editorial/editorial_0566.xml)

3.5 THE MASS TRANSIT SYSTEM

3.5.1 Definitions

For the purposes of this project, *public transportation*, or *mass transit*, as in the American Public Transportation Associations (APTA) definition, which is "transportation by bus, rail, or other conveyance, either publicly or privately owned, providing to the public general or special service (but not including school buses or charter or sightseeing service) on a regular and continuing basis." A *transit agency* (transit system) is an entity responsible for administering and managing transit activities and services. Transit agencies can directly operate the service or contract out for all or part of the service.

A *mode* is the system for carrying transit passengers described by specific right-of-way, technology, and operational features (e.g., bus, rail). When more than one mode of service is operated, it is a multimodal transit agency. Transit data are generally collected by mode. *Intermodal* (multimodal) are those issues or activities that involve more than one mode of transportation, including transportation connections, choices, cooperation, and coordination of various modes. Definitions of public transit modes are provided as the last section of this chapter.

Fixed-route services are those provided on a repetitive, fixed-schedule basis along a specific route with vehicles stopping to pick up and deliver passengers to specific locations; each fixed-route trip serves the same origins and destinations. Fixed-route services may include occasional route deviations on a discretionary basis. Demand-response services are the only form of non-fixed-route services.

3.5.2 System Size

Approximately 6,000 public transportation systems operate in the United States and Canada. Most of these agencies operate more than one mode of service. Tables 3-27 and 3-28 provide some basic statistics on public transit vehicle characteristics and employment, respectively. The number of transit agencies and number of vehicles providing each mode of service are listed in Table 3-29. More than 2,250 agencies provide bus service, about 5,250 operate demand-response service, and 150 operate other modes (i.e., rail and ferryboat). Two-thirds of U.S. public transportation agencies provide service designed for senior citizens and persons with disabilities. Many public transit agencies contract service with private

(*text continues on page 60*)

TABLE 3-25 Aviation Operational Sequences, Traffic Flow, and Historical Emergency Response

Operational Sequences	Traffic Flow		Historical Emergency Response	
	Traffic Types	Traffic Patterns	Short Term (2 hr)	Long Term (>2 hr)
Vehicles: Airline flights operate on fixed city-pair routes. Air taxi operators provide on-demand service. Private operators fly in 'anytime, anywhere' mode. **Passengers:** Intermodal transport at origin and destination. Peak airline demand on weekdays, primarily Monday and Friday.	**Normal:** A mix of business travelers and tourists. Airline travel is preplanned, often with lengthy lead times. **Constraining Emergencies:** Weather conditions (low visibility, heavy rain and ice at airports) can seriously disrupt travel, resulting in delays and cancellations. **Expanding Emergencies:** Emergency plans (Civil Reserve Air Fleet, Emergency Medical Service operators, USCG, National Guard) can be executed with ability to operate when and where needed.	**Normal Operations:** Airlines use 'hub and spoke' concept. Other operators use 'anytime - anywhere' concept. **Emergencies:** 'Hub and spoke' can be abandoned in favor of 'anytime - anywhere' concept for evacuations and for bringing in emergency responders.	**Cancel Departures:** Under control of ATC System Command Center, departures can be held or canceled. **Reroute Arrivals:** Under local ATC or ATC SCC direction, flights redirected to alternate airports. **Other Services:** EMS response, local law enforcement aircraft, USCG, National Guard for search, rescue, delivering emergency workers, etc.	◆ Reroute Service ◆ Evacuate People ◆ Suspend Fares ◆ Inform Passengers ◆ Dedicate Aircraft to First Responders. ◆ Transport Supplies ◆ Civil Reserve Air Fleet ◆ EMS Response **Examples: WTC and Pentagon 9/11, Air Florida crash, floods**

TABLE 3-26 Aviation Control Options, Operational Limits, and Existing Authority

Control Options	Operational Limits			Existing Authority
Short Term (2 hr)	Long Term (>2 hr)	Short Term (2 hr)	Long Term (>2 hr)	Options
◆ **Reroute Service, Suspend Departures** ◆ **Suspend Fare Collection** (CRAF) ◆ **Add or Refocus Service** (CRAF) ◆ **Substitute Service** (ground transportation) ◆ **Transport FR** ◆ **ATC, ARINC Communications Ensures Control** ◆ **Local Law Enforcement Coordination** ◆ **Evacuate Terminals**	**Same as short term and:** ◆ **Implement National Response Plan** ◆ **Implement CRAF, SARDA Plans** ◆ **Coordinate Mutual Assistance**—Police and Fire, Volunteer Organizations, USCG, National Guard, etc. ◆ **Convert Cargo Aircraft for Medical Transport** ◆ **Media** (inform public)	**Reroute/Suspend Service**—Fuel Limitations **Suspend Fares**—overcrowding, revenue loss **Add/Refocus Service**—Airport Capacity Limits **Substitute Service**—(e.g., ground transit) inefficient **Transport FR**—jurisdictional issues, command structure **ATC, ARINC Communications**—May not apply to EMS and other local services **Law Enforcement Coordination**—Jurisdiction issues, incompatible communications **Evacuate Terminals**—Limited ground transport	**Same as short term and:** ◆ **Implement Emergency Plan**—Lead Time; Local Confusion ◆ **Implement CRAF, SARDA Plans**—Funding Limitations, Lead Time ◆ **Coordinate Assistance** (Police, fire, volunteers, USCG, National Guard, etc.)—Coordination Issues ◆ **Convert Cargo Aircraft for Medical Transport**—Lead Time ◆ **Media (inform public)**—Lack of Control	◆ **Reroute/Suspend Service**—airlines, Air Traffic Control, local and state government. ◆ **Suspend Fares**—local, state, and federal government. ◆ **Add/Refocus Service**—local, state, and federal government, first responder organization ◆ **Substitute Service**—airlines, local and state government. ◆ **Transport FR**—first responder organization, local and state government . ◆ **ATC, ARINC Communications**—federal government, airlines ◆ **Implement Emergency Plan**—local, state, and federal government, ◆ **Implement CRAF, SARDA Plans**—local, state, and federal government, first responder organization, airlines ◆ **Coordinate Mutual Assistance**—local and state government, first responder organization ◆ **Convert Cargo Aircraft to Medical Transport**—federal government, airlines ◆ **Media**—industry ◆ **Evacuate Terminals**—first responder organization, local and state government, airlines

TABLE 3-27 National Public Transit System Vehicle Characteristics

Vehicles, Total	**141,392**
* Active	134,271
* Age, Average (years)	10.3
* Air-conditioned	89.8%
* Lifts, Wheelchair	56.8%
* Ramps, Wheelchair	14.5%
* Accessible Only via Stations	4.2%
* Power Source, Diesel or Gasoline	70.9%
* Power Source, Alternative	26.2%
* Rehabilitated	12.2%

(Source: APTA, 2001)

operators, further increasing the number of public transportation providers. The public transportation fleet comprises 134,000 vehicles in active service. Buses represent 57% of these vehicles; demand-response vehicles, 26%; heavy rail cars, 8%; commuter rail cars, 4%; light rail cars, 1%; and all other modes, 5%.

3.5.3 System Use

Based on APTA data, in 2001, 9.7 billion trips were made on the U.S. public transportation system, an increase of 3% over the previous year, outpacing growth in other travel systems. In the past 6 years, public transportation ridership in the United States has grown by more than 24%, faster than highway or air travel. More than 14 million people ride on public transportation each weekday. The U.S. DOT estimates another 25 million use public transportation less frequently but regularly. APTA data suggest that 54% of all trips end at workplaces, 15% of trips go to schools; 9% to shop; 9% to social visits; and 5% to medical appointments. Table 3-30 summarizes public transit use.

Almost one-half of the nation's Fortune 500 companies, representing over $2 trillion in annual revenue, are headquartered in transit-intensive metropolitan areas. Public transit is thought to facilitate employee recruitment, in addition to increasing employee reliability and reducing absenteeism and turnover. Public transportation is also important for 30 million rural nondrivers, including senior citizens, low-income families, and people with disabilities. One-fourth of today's 75+ age group does not drive. Passengers older than 65 years and younger than 18 years compose 20% of the national riders. By the year 2020, 40% of the U.S. population will be senior citizens. Table 3-31 lists the percent of workers that use public transit in the urban areas with greatest worker use of public transit.

TABLE 3-28 National Public Transit System Vehicle Employment

Employees, Operating	**357,266**
* Vehicle Operations	228,091
* Vehicle Maintenance	62,404
* Non-vehicle Maintenance	29,963
* General Administration	36,808
Employees, Capital	**13,490**
Diesel Fuel Consumed (gallons)	**744,663,000**
Other Fuel Consumed (gallons)	**112,088,000**
Electricity Consumed (kwh)	**5,609,846,000**

(Source: APTA, 2001)

TABLE 3-29 Number of Transit Agencies and Vehicles by Mode

MODE	Agencies	Vehicles
Bus	2,264	76,075
Commuter Rail	21	5,124
Demand Response	5,251	34,661
Heavy Rail	14	10,718
Light Rail	26	1,366
Trolleybus	5	600
Vanpool	67	5,519
Aerial Tramway	2	ND
Automated Guideway	5	45
Cable Car	1	40
Ferryboat (b)	42	107
Inclined Plane	4	8
Monorail	2	8
Total	6,000 (a)	134,271

(a) Total is not sum of all modes since many agencies operate more than one mode.
(b) Excludes international, rural, rural interstate, island, and urban park ferries.

3.5.4 Financing

Transit agencies depend on many sources of funds for capital and operating expenses. None of the transit agencies are self-sufficient based on fares alone. Over the past decade, transit agencies have been asked to comply with more stringent emissions regulations, in addition to local directives to adopt

TABLE 3-30 Public Transit Use Statistics

Trips, Unlinked Passenger, Average Weekday	32,994,000
Trips, Unlinked Passenger, Annual	9,652,816,000
Trips to Workplace	54%
Trips to Schools	15%
Trips to Shop	9%
Trips, Social	9%
Trips, Medical appointments	5%
Miles, Passenger	49,070,383,000
Trip Length, Average (miles)	5.1
Miles, Vehicle Total	4,196,245,000
Miles, Vehicle Revenue	3,715,210,000
Hours, Vehicle Total	281,723,000
Hours, Vehicle Revenue	252,236,000
Speed, Vehicle in Revenue Service, Average (m.p.h.)	14.7

(APTA, 2001)

TABLE 3-31 Percent of Workers Using Public Transit in the Top 12 Urban Areas with Worker Use of Public Transit

Urban Area	Urban Area	Central City
New York-Newark, NY-NJ-CT	29.0	52.8
Washington, DC-MD-VA	13.4	33.2
Boston, MA-NH-RI	12.3	32.3
San Francisco-Oakland, CA	16.2	31.1
Chicago, IL-IN	12.6	26.1
Philadelphia, PA	9.9	25.4
Pittsburgh, PA	8.0	20.5
Baltimore, MD	7.6	19.5
Seattle, WA	7.6	17.6
Atlanta, GA	4.2	15.0
Minneapolis-St. Paul, MN	5.4	14.6
New Orleans, LA	7.3	13.7

(2000, U.S. Census Bureau)

new technologies and clean fuels, and federal requirements for provision of services and facilities for people with disabilities (i.e., the ADA). Generally, and predominantly, these activities were financed by funds other than those from fares.

Public transportation funds come from two main sources, capital and operating. Understanding the breakdown may help to understand funding of security-related projects. Table 3-32 summarizes public transit financial statistics.

Capital funds are used to finance infrastructure needs such as new construction and rehabilitation of existing facilities. The federal government contributes 50% of all capital funding for public transportation. In Fiscal Year 2003, up to 80% of the total capital cost may be federally funded. The balance is typically paid for by a combination of state and local funds. Many state and local governments provide more than the required minimum 20% of matching funds and in many cases, capital projects are financed solely by state and local funds.

TABLE 3-32 Public Transit Financial Statistics (APTA, 2001)

Agencies, Number of	6,000
Fares Collected, Passenger	$8,891,063,000
Fare per Unlinked Trip, Average	$0.92
Expense, Operating Total (a)	$23,516,916,000
* Salaries and Wages (b)	$10,626,938,000
* Fringe Benefits (b)	$5,705,586,000
* Services (b)	$1,389,348,000
* Fuel and Lubricants (b)	$716,776,000
* Materials and Supplies, Other (b)	$1,645,758,000
* Utilities (b)	$772,447,000
* Casualty and Liability (b)	$492,802,000
* Purchased Transportation (b) (c)	$2,976,508,000
* Other (b)	($809,247,000)
* Vehicle Operations (c)	$10,438,750,000
* Vehicle Maintenance (c)	$4,348,422,000
* Non-vehicle Maintenance (c)	$2,290,124,000
* General Administration (c)	$3,463,113,000
Expense, Capital Total	$11,418,662,000
* Rolling Stock (vehicles)	$4,027,344,000
* Facilities	$6,301,830,000
* Other (equipment and services)	$1,089,488,000

(a) Sum of (b) lines OR sum of (c) lines.

Operating funds provide income for operational expenses. Most operating funds originate from local sources (73%). Passenger fares pay 35% of operating expenses, local governments pay 24%, and nongovernmental sources and taxes levied by the transportation system, tolls, and fees, pay 14%. State and federal governments contribute 22% and 5%, respectively.

Funding of security and emergency preparedness fall under both operating expenses (e.g., plan development and training) and capital expenses (e.g., cameras and alarms). The overlap of safety, security, and emergency preparedness allows financing of emergency-related preparations from various sources. FTA funds provided to transit agencies may be applied to security and emergency response. Some of the funds recently available to specifically address emergencies include grants from the Office of Domestic Preparedness for public transit security and emergency response. In addition, FTA has made grants to 86 transit agencies for up to $50,000 to be applied to emergency response drills. Transit agency expenditures on security, their security increases since the terrorist attacks of September 11, 2001, and their security priorities are assessed in a recent survey by APTA.[1]

3.5.5 General Organization

Depending on the agency, public transit agencies may provide service for a city, a county, or a multicounty/multicity metropolitan area. Boards of directors/trustees typically oversee transit agencies. Depending on the agency, the boards may include governor-appointed members, county supervisors, state officials, members of the public, the mayor, and/or city council representatives. Advisory committees often provide additional input. Some state governors have veto power over board decisions. The board commonly selects an executive director/general manager (GM) to administer the agency. Typically, there are separate divisions for finance and administration; engineering and project management; human resources; and operations. Safety and emergency plans may fall under operations or another division (e.g., legal affairs) or it may be a separate division of its own depending on the agency. Often, the safety and security office reports directly to the GM, where operational responsibility ultimately rests. However, because transit is a public service, safety and security issues can readily become a political matter and thus invite the attention and actions of the board and public officials.

3.5.6 Operations

An operations control center or dispatcher coordinates transit agency service. Nearly all public transit vehicles are

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[1] Survey of the United States Transit System Security Needs and Funding Priorities, April 2004, available at the American Public Transit Association website: http://www.apta.com/services/security/documents/security_survey.pdf

equipped with two-way radios. Many contain more sophisticated communications systems, tracking capabilities, recording devices, and emergency notification systems. Although tracking can provide location information, it does not ensure safety or security of contents within a vehicle.

General system operations for the three most common modes of public transit, representing approximately 90% of public transit vehicles, are described below.

- Buses—Fixed-route bus service varies by transit agency in vehicle type (e.g., van or bus), length (45, 40, 35, 30 foot); fuel (diesel, compressed natural gas (CNG), liquefied natural gas (LNG), hybrid); floor height; service (e.g., frequency of stops, cost, and number of passengers); and effectiveness (e.g., on-time performance and cost of service). Bus service is planned by day of the week to allow for reduced demand during weekends; time of the day to respond to work commuters; and to holiday and special events needs. Buses and drivers are generally assigned to the same bus and the same route. As such, the drivers not only become familiar with their vehicle, the service route, the neighborhoods, and repeat passengers, but also can notice new riders. Before pull-out, the driver is to inspect the vehicle for mechanical and operational soundness and, in some cases, for unusual or suspicious objects. At the end of the route, the driver or the cleaning crew will look inside the bus for misplaced property and other objects. The bus is cleaned, serviced, and returned to operation at the next pull-out.
- Demand Response (dial-a-ride, paratransit)—Demand-response bus service varies by transit agency in vehicle type (i.e., van or bus), length, and fuel type (gasoline, diesel, CNG, LNG, hybrid). Demand-response service users call to schedule their trip, similar to a taxi service. Lead time for scheduling, hours of operation, and number of passengers that share a ride (and hence, number of stops) varies. The primary objective of this service is to meet the requirements of the ADA by providing transportation for persons with disabilities. Regular fixed-service vehicles are increasingly being equipped to facilitate travel by a larger proportion of persons with disabilities; thus the extent of demand-response vehicles depends both on the size and demographics of the community and the characteristics of the fixed-route fleet (i.e., low-floor and kneeling buses). The pull-out inspection requirements, driver assignments, route assignments, and bus inspections are similar to those required on buses. However, the driver commonly provides closer and more personal support to this clientele.
- Heavy Rail (subways, elevated, metro, etc.)—Operations vary by transit agency in accordance with local requirements; system complexity; system age, vehicle type and arrangement (e.g., subway, elevated, and number of cars per train); service (e.g., frequency of stops, express service, local service, cost, and number of passengers); and effectiveness. Service frequency varies between rush-hour and non-rush-hour times of day and days of week. Trains and operators are generally assigned to the same train and the same route. Operator choices are limited by the fixed-guideway system, and instructions regarding train speed, stops, and so forth are generally provided by the operations control center (dispatcher). In an emergency, detour options are very limited and evacuations can be difficult because of the danger caused by the electrified third rail and the confines of the physical system (e.g., tunnels, elevated structures, semi-enclosed tracks, height of the train, and ventilation issues). Rail operators commonly have minimal interaction and, by extension, much less familiarity with their passengers than bus drivers. However, other personnel assigned to the train, such as the door engineer or transit police (including plain clothes police) have a greater ability to observe, report, and, if needed, interfere. Post-service inspections identify repair and service requirements and look for misplaced objects. Cars are cleaned and serviced and returned to operation at the next pull-out. Operational requirements are increasingly including requirements to look for unusual or suspicious objects.

3.5.7 Emergency Plans and Organization

All transit agencies have some plans for emergencies, which often include preset alternate routes and schedules. The primary objective of these plans is to avoid problem areas and provide assistance to first-responders as needed. These objectives remain the same whether the event is a more common emergency, such as snow storms or water main breaks, or a terrorist threat. The extent to which plans address terrorist-related emergencies varies significantly between agencies. According to the FTA Office of Safety and Security, emergency response plans that specifically address WMD were developed at the 30 largest public transit agencies as of the end of 2003, and the number of agencies with these plans is continuing to increase. The FTA provides consulting services for agencies developing these plans, which may also include coordinated responses with state and federal agencies, such as the FBI, CDC, FEMA and other parts of the DHS.

Because the use of emergency response plans (not necessarily those related to WMD) is expected with some frequency within transit agencies, decisions on how and when to implement these plans are kept at an operational level. For each emergency type, the operations control center and field personnel have specific procedures to follow as set in the agency's emergency response plan. Initially, at the site of an incident, the first respondents have direct, local control of traffic flow, including public transit. This control is quickly transferred to a rapidly established incident command post, which is typically controlled by either the police or fire department, depending on the event. Under severe emergencies, for example, for those that involve WMD, federal agencies may be involved and may assume control of the incident command post, thereby becoming the key executors of response operations. The transit operations control center, or dispatcher, coordinates transit service with the incident command post. Transit agency representatives are either physically present at the incident command post (which may be a vehicle provided by the transit agency) or are in frequent communication via telephone or radio. The transit agency may also have field personnel providing information through the agency's operation control center to the incident command post.

Thus, emergency response decisions in transit agencies follow preset plans, which can be superseded by orders from the incident command post. These actions do not require explicit consultation or approval within the transit agency beyond the operations division. A transit representative assists the command post in assessing public transit options such as changes in routes, tunnel ventilation, provision of assistance to an adjacent transit authority, or dedication of vehicles to emergency worker needs.

To assist with emergency plan development, the FTA has recently funded vulnerability assessments of the 37 largest transit systems. In 2003, the FTA released a document on "Handling of Chemical and Biological Incidents in Tunneled Environments," which further developed appropriate emergency responses. A similar report on surface transit operations has also been released. Rail systems are addressed through the FTA/APTA Rail Safety Audit Program that promotes and oversees state oversight of fixed-guideway systems. The program includes emergency response plans, training, and security, and guidance on ventilation regarding the most appropriate way to change ventilation in vehicles and tunnels under different emergency conditions. Typically, transit agencies rapidly coordinate with fire departments when ventilation-related emergency actions are needed. Under some conditions, the fire department may assume control of a transit agency's tunnel ventilation through remote control of fan direction and speed.

Additional guidance in emergency plan development has been available through 2-day workshops offered throughout the country by the US DOT Volpe Center. The workshops, entitled "Connecting Communities," include transit agency personnel and their local first responders to identify emergency plan strengths and weaknesses, with consideration of emergencies ranging from the relatively common to WMD. Transit agency personnel may also obtain training on topics such as system security, general emergency management, threat management, and emergency response to hijackings, transit explosives incident management, and WMD through courses offered by the FTA's Transit Safety Institute.

3.5.8 Historical Emergency Actions

Public transportation has been critical in maintaining basic access, mobility, and safety for the public during both natural and human-caused emergencies. On 9/11, in the New York City area, the public transportation systems moved people safely away from the World Trade Center disaster. Early response examples included informing passengers of alternative transit via telecommunication monitors, suspending bus and rail fares to facilitate evacuation, and reopening bridges and tunnels with more outbound lanes. Emergency changes in the New York City Metropolitan Transportation Authority (MTA) service was quickly coordinated with New Jersey Transit. Later responses included provision of shuttle service to what become known as Ground Zero, with buses dedicated to search and rescue teams, emergency responders, and the Salvation Army. Two light rail cars were stripped and dedicated to the transport of personnel and equipment to Ground Zero.

In the Washington, DC, area, hundreds of thousands of residents flooded the transportation system when workplaces and schools were closed after the attack on the Pentagon. Passengers were informed of station changes via the transit authority Web page, flyers, telephone message centers, and media announcements. Service was increased to meet the needs of an early rush hour. Additional buses were assigned to provide rest stations for Pentagon rescue workers and to provide transportation for search and rescue teams. The following day, several buses were assigned to the DC Police to assist in deploying officers at strategic locations. In the wake of the attacks of September 11, many adjacent transit providers coordinated their efforts not only in the New York City and Washington, DC, regions, but also around airports throughout the country, where air travel was suspended. Nationwide, transit systems evacuated tens of thousands of travelers from closed airports in major cities. Not a single life was lost among the millions of people traveling on public transportation that day.

Other examples of emergency use during natural disasters include the record snowfall that hit the East Coast over the 2003 President's Day weekend. Buses and trains at many systems kept the public moving from Washington, DC, to Boston. During the peak of the storm, the Rhode Island Public Transit Authority extended some bus service from its regular closing time of midnight until 3 a.m. The change was made to ensure that riders would not get stranded in the snow without access to transportation. In Philadelphia, the Southeastern Pennsylvania Transportation Authority (SEPTA) provided transportation for thousands of stranded passengers when the Philadelphia Airport shut down for approximately 3 days because of the heavy snow. Along with operating service at 70 to 75% of normal schedules on average, SEPTA also kept its paratransit services operating during the storm. In January 2003, an ice storm hit the Carolinas, leaving millions without power and heat. The Charlotte Area Transit System (CATS) altered operations to provide transportation to temporary shelters across the area.

3.5.9 System Summary Matrix

Table 3-33 provides a matrix that summarizes mass transit operational sequences, traffic flow, and historical emergency response. Table 3-34 summarizes mass transit control options, operational limits, and existing authority.

TABLE 3-33 Mass Transit Operational Sequences, Traffic Flow, and Historical Emergency Response

Operational Sequences	Traffic Flow		Historical Emergency Response	
	Traffic Types	Traffic Patterns	Short Term (2 hr)	Long Term (>2 hr)
Vehicles: Dispatched on set routes, schedules, and stops (e.g., bus stops, train stations). For demand response service routes, schedules and stops vary. **Passengers:** Embark and debark at set or arranged stops/stations. Peak demand is for service weekdays—mornings and evenings.	**Normal:** Workers, students, shoppers, and tourists on or near schedule. Peak demand during the morning and evening hours, and during some events. **Constraints:** Reduced or suspended service during severe weather (e.g., snow, hurricane).	**Rush Hours:** Toward urban areas, schools, and work centers. **Off-Peak:** To and from schools, shopping, entertainment, etc. **Emergencies:** Route general traffic away from and first responders toward emergency area. Off schedule and on and off routes.	**Stop Service:** At event sites, at suspicious sites, and as directed. **Reroute Service:** Around emergency site, suspicious areas, traffic congestion. **Suspend Fares:** During area evacuations to reduce traffic during spiked demand (special events). **Other Options:** Promote travel alternatives, discourage use, issue transfers, provide special service.	◆ **Reroute Service** ◆ **Evacuate People** ◆ **Suspend Fares** ◆ **Inform Passengers** ◆ **Dedicate Vehicles to First Responders.** ◆ **Modify Vehicles for Supplies** ◆ **Borrow Vehicles and Drivers from Nearby Transit Authorities** **Examples:** WTC and Pentagon 9/11, Baltimore chemical spill (7-18-01).

TABLE 3-34 Mass Transit Control Options, Operational Limits, and Existing Authority

Control Options		Operational Limits		Existing Authority
Short Term (2 hr)	**Long Term (>2 hr)**	**Short –Term (2 hr)**	**Long Term (>2 hr)**	**Options**
◆ **Stop/Reroute Service** ◆ **Suspend Fares** ◆ **Add/Refocus Service** ◆ **Substitute Service** (buses instead of trains); ◆ **Obtain FR Help** ◆ **Media Assistance** ◆ **Evacuate Vehicles** ◆ **Evacuate Station**	Same as short term and: ◆ **Get Right of Way** ◆ **Borrow or Buy Vehicles/Drivers** ◆ **Receive Assistance**—From Police, Traffic Control, DOT, etc. ◆ **Modify Vehicles** ◆ **Employer Help** (stagger work hours) ◆ **Media** (inform on all) ◆ **State and Local Government** (special exemption—use of roads)	◆ **Stop/Reroute Service**—limited choices ◆ **Suspend Fares**—overcrowding, revenue loss ◆ **Add/Refocus Service**—lack of resources ◆ **Substitute Service**—(e.g., buses vs. trains) inefficient, lack of resources; ◆ **First Responder Help**—different command structure, operations, etc. ◆ **Media Assistance**—inadequate coordination, coverage, frequency, etc. ◆ **Evacuate Vehicles and Stations**	Same as short-term and: ◆ **Get Right of Way**—traffic issues, resentments ◆ **Borrow/Buy Vehicles/Drivers**—lack of funds, stock, operators ◆ **Receive Assigned Assistance**—lack of resources, commitment, experience ◆ **Modify Vehicles**—resources, time ◆ **Other Long—Term Help**—employers, media, state and local government ◆ **Fuel Access**—depends on continuity of fuel deliveries.	◆ **Stop/Reroute Service**—first responder organization, transit agency, local and state government. ◆ **Suspend Fares**—first responder organization, transit agency, local and state government. ◆ **Add/Refocus Service**—transit agency, local and state government. ◆ **Substitute Service**—transit agency, local and state government. ◆ **First Responder Help**—first responder organization, local and state government. ◆ **Media Assistance**—industry ◆ **Get Right of Way**—first responder organization, local and state government. ◆ **Borrow/Buy Vehicles/Drivers**—transit agency, local, state, and federal government . ◆ **Modify Vehicles**—transit agency, local government. ◆ **Employer Help**—industry ◆ **Special Exemption**—local and state government ◆ **Evacuate**—first responder organization, transit agency, local and state government.

3.5.10 Other Mass Transit Definitions

The mass transit definitions listed below are from the APTA "Glossary of Transit Terminology."

- Aerial Tramway: An electric system of aerial cables with suspended unpowered passenger vehicles. The vehicles are propelled by separate cables attached to the vehicle suspension system and powered by engines or motors at a central location not on board the vehicle.
- Automated Guideway: An electric railway operating without operators or other crew on board the vehicle.
- Bus (Motorbus): A rubber-tired, self-propelled, manually steered vehicle with fuel supply carried on board the vehicle. Types include advanced design, articulated, charter, circulator, double deck, express, feeder, intercity, medium-size, new look, sightseeing, small, standard-size, subscription, suburban, transit and van.
- Cable Car: An electric railway operating in mixed street traffic with unpowered, individually-controlled transit vehicles propelled by moving cables located below the street surface and powered by engines or motors at a central location not on board the vehicle.
- Commuter Rail: Railroad local and regional passenger train operations between a central city, its suburbs and/or another central city. It may be either locomotive-hauled or self-propelled and is characterized by multi-trip tickets, specific station-to-station fares, railroad employment practices, and usually only one or two stations in the central business district. Also known as "suburban rail."
- Demand Response: Non-fixed-route service using vans or buses with passengers boarding and alighting at pre-arranged times at any location within the system's service area. Also called "Dial-a-Ride."
- Ferry boat: A boat providing fixed-route service across a body of water.
- Heavy Rail: An electric railway with the capacity for a "heavy volume" of traffic and characterized by exclusive rights-of-way, multi-car trains, high speed and rapid acceleration, sophisticated signaling, and high platform loading. Also known as "rapid rail," "subway," "elevated (railway)" or "metropolitan railway (metro)."
- Inclined Plane: A railway operating over exclusive right-of-way on steep grades with unpowered vehicles propelled by moving cables attached to the vehicles and powered by engines or motors at a central location not on board the vehicle.
- Light Rail: A metropolitan electric railway system that can operate single cars or short trains along exclusive right-of-way at ground level, aerial structures, in subways, or on streets. Passengers are boarded and discharged at the track or car floor level.
- Monorail: An electric railway in which a rail car or train of cars is suspended from or straddles a guideway formed by a single beam or rail. Most monorails are either heavy rail or automated guideway systems.
- Trolley Bus: An electric, rubber-tired transit vehicle, manually steered, propelled by a motor drawing current through overhead wires from a central power source not on board the vehicle. Also known as "trolley coach" or "trackless trolley."
- Van Pool: An arrangement in which a group of passengers share the use and cost of a van in traveling to and from pre-arranged destinations together.

APPENDIX A

Chemical Threat Information

A.1 POSSIBLE TYPES OF AGENTS

There is a wide range of chemicals that are potentially attractive to terrorists, whether at a fixed site or during transportation. There are numerous sources that can be consulted for lists of such chemicals, among them being the following:

- The EPA Risk Management Program (RMP) 40 CFR Part 68 lists 77 regulated toxic chemicals. See www.epa.gov/ceppo.
- The OSHA Process Safety Management (PSM) Standard 29 CFR 1910.119 provides a list of 136 toxic and highly reactive hazardous chemicals. See (www.osha.gov).
- The FBI Community Outreach Program for Manufacturers and Suppliers of Chemical and Biological Agents, Materials, and Equipment has a table of 42 industrial chemical materials and agents that “may be more likely to be used in furtherance of WMD terrorism.” See (http://www.aiche.org/ccps/pdf/fbi_wmd.pdf)
- The Australia Group list of chemical and biological weapons provides a list of 54 chemical weapons precursors. See www.australiagroup.net
- The Chemical Weapons Convention (CWC) provides three toxic chemicals and 11 precursors under Schedule 2 and 17 toxic chemicals under Schedule 3. See www.cwc.gov.
- The Department of Transportation’s (DOT’s) *2004 Emergency Response Guidebook* contains guides to responding to dangerous goods/hazardous materials incidents. Each guide is designed to cover a group of materials that have similar chemical and toxicological properties. This may be obtained online through http://hazmat.dot.gov/pubs/erg/gydebook.htm.

The above sources list at most a few hundred chemicals. In actuality there may be “literally tens of thousands of poisonous chemicals” that might be of some use to terrorists (Kupperman and Kamen 1989). Mullen (1978) cites an estimate of “well over 50,000” for the number different organophosphate (of which sarin is one) alone. Purver (1995) provides a list of chemical agents specifically mentioned in the then-current literature on terrorism: insecticides such as nicotine sulfate, DFP (diisopropylphosphorofluoridate), parathion, and TEPP; herbicides such as 2,4D and 2,4, 5T (against plants), TCDD (dioxin), and benzidine (112-14); “blood agents” such as hydrogen cyanide and cyanogen chloride; “choking agents” such as chlorine, phosgene (carbonyl chloride), and chloropicrin; “blistering agents” such as sulfur mustard, nitrogen mustard, and lewisite; and “nerve agents” such as tabun, sarin, VX, and soman. Other chemicals mentioned include: Prussic acid (hydrocyanic acid), lysergic acid (LSD), aminazin, pheromones, pure nicotine, phosgene oxime (CX), arsenic, Cobalt-60, compound 1080 (sodium fluoroacetate), arsine, nickel carbonyl, and strychnine. Toxic chemicals can be categorized as shown below based upon Cordesman, 1996.

NERVE AGENTS: Agents that quickly disrupt the nervous system by binding to enzymes critical to nerve functions, causing convulsions and/or paralysis. Must be ingested, inhaled, and absorbed through the skin. Very low doses cause a running nose, contraction of the pupil of the eye, and difficulty in visual coordination. Moderate doses constrict the bronchi, cause a feeling of pressure in the chest, and weaken the skeletal muscles and cause fibrillation. Large doses cause death by respiratory or heart failure. (Can be absorbed through inhalation or skin contact.) Reaction normally occurs in 1–2 minutes. Death from lethal doses occurs within minutes, but artificial respiration can help and atropine and the oximes act as antidotes. The most toxic nerve agents kill with a dosage of only 10 milligram-minutes per cubic meter, versus 400 for less lethal gases. Recovery is normally quick, if it occurs at all, but permanent brain damage can occur. Examples of nerve agents are:

- Tabun (GA)
- Sarin (GB)—nearly as volatile as water and delivered by air. A dose of 5 mg-min/m^3 produces casualties, a respiratory dose of 100 mg-min/m^3 is lethal. Lethality lasts 1–2 days.
- Soman (GD)
- GF
- VR-55 (Improved Soman) A thick oily substance which persists for some time.
- VK/VX/VE/VM/VG/VS—Persistent agents are roughly as heavy as fuel oil. A dose of 0.5 mg-min/m^3 produces casualties, a respiratory dose of 10 mg-min/m^3 is lethal. Lethality lasts 1–16 weeks.

BLISTER AGENTS: Cell poisons that destroy skin and tissue, cause blindness upon contact with the eyes, and which can result in fatal respiratory damage. Can be colorless or black oily droplets. Can be absorbed through inhalation or skin contact. Serious internal damage if inhaled. Penetrates ordinary clothing. Some have delayed and some have immediate action. Actual blistering normally takes hours to days, but effects on the eyes are much more rapid. Mustard gas is a typical blister agent and exposure to concentrations of a few milligrams per cubic meter over several hours generally causes blisters and swollen eyes. When the liquid falls onto the skin or eyes it has the effect of second or third degree burns. It can blind and cause damage to the lungs leading to pneumonia. Severe exposure causes general intoxication similar to radiation sickness. HD and HN persist up to 12 hours. L, HL, and CX persist for 1–2 hours. Short of preventing exposure, the only treatment is to wash the eyes, decontaminate the skin, and treat the resulting damage like burns. Examples of blister agents are:

- Sulfur Mustard (H or HD): A dose of 100 mg-min/m^3 produces casualties, a dose of 1,500 mg-min/m^3 is lethal. Residual lethality lasts up to 2–8 weeks.
- Distilled Mustard (DM)
- Nitrogen Mustard (HN)
- Lewisite (L)
- Phosgene Oxime (CX)
- Mustard Lewisite (HL)

CHOKING AGENTS: Agents that cause the blood vessels in the lungs to hemorrhage, and fluid to build-up, until the victim chokes or drowns in his or her own fluids (pulmonary edema). Provide quick warning though smell or lung irritation. Can be absorbed through inhalation. Immediate to delayed action. The only treatment is inhalation of oxygen and rest. Symptoms emerge in periods of seconds up to three hours after exposure. Examples of choking agents are:

- Phosgene (CG)
- Diphosgene (DP)
- PS Chloropicrin
- Chlorine Gas

BLOOD AGENTS: Kill through inhalation. Provide little warning except for headache., nausea, and vertigo. Interferes with use of oxygen at the cellular level. CK also irritates the lungs and eyes. Rapid action and exposure either kills by inhibiting cell respiration or it does not—casualties will either die within seconds to minutes of exposure or recover in fresh air. Most gas masks have severe problems in providing effective protection against blood agents, examples of which are:

- Hydrogen Cyanide (AC)—a dose of 2,000 mg-min/m^3 produces casualties. A dose of 5,000 mg-min/m^3 is lethal. Lethality lasts 1–4 hours.
- Cyanogen Chloride (CK)—a dose of 7,000 mg-min/m^3 produces casualties. A dose of 11,000 mg-min/m^3 is lethal. Lethality lasts 15 minutes to one hour.

BIOLOGICAL TOXINS : Biological poisons causing neuromuscular paralysis hours or days after exposure. Formed in food or cultures by the bacterium *Clostridium botulinum*. Produce highly fatal poisoning characterized by general weakness, headache, dizziness, double vision and dilation of the pupils, paralysis of muscles, and problems in speech. Death is usually by respiratory failure. Antitoxin therapy has limited value, but treatment is mainly supportive. An example is Botulin toxin (A), of which there are six distinct types Four of these are known to be fatal to man. An oral dose of 0.001 mg is lethal. A respiratory dose of 0.02 mg-min/m^3 is also lethal.

DEVELOPMENTAL WEAPONS: A new generation of chemical weapons is under development (this statement written in 1996). The only publicized agent is perfluoroisobutene (PFIB), which is an extremely toxic, odorless, and invisible substance produced when PFIB (Teflon) is subjected to extreme heat under special conditions. It causes pulmonary edema or dry-land drowning when the lungs fill with fluid. Short exposure disables and small concentrations cause delayed death. Activated charcoal and most existing protection equipment offer no defense. Some sources refer to “third” and “fourth” generation nerve gases, but no technical literature seems to be available.

RIOT CONTROL AGENTS: Agents that produce temporary irritating or disabling effects. They cause flow of tears and irritation of upper respiratory tract and skin when in contact with the eyes or inhaled. They can cause nausea and vomiting: can cause serious illness or death when used in confined spaces. CS is the least toxic gas, followed by CN and DM. Symptoms can be treated by washing the eyes and/or removal from the area. Exposure to CS, CN, and DM produces immediate symptoms. Staphylococcus produces symptoms in 30 minutes to four hours, and recovery takes 24–48 hours. Treatment of Staphylococcus is largely supportive:

Tear Gases:
- Chlororacetophenone (CN)
- O-Chlorobenzyl-malononitrile (CS)

Vomiting Gases: (cause irritation, coughing, severe headache, tightness in chest, nausea, and vomiting):
- Adamsite (DM)
- Staphylococcus

INCAPACITATING AGENTS: Agents that normally cause short term illness and psychoactive effects (delirium and hallucinations). Can be absorbed through inhalation or skin contact. The psychoactive gases and drugs produce unpredictable effects, particularly in the sick, small children, elderly, and individuals who already are mentally ill. In rare cases they kill. In others, they produce a permanent psychotic condition. Many produce dry skin, irregular heart beat, urinary retention, constipation, drowsiness, and a rise in body temperature, plus occasional maniacal behavior. A single dose of 0.1 to 0.2 milligrams of LSD-25 will produce profound mental disturbance within a half hour that lasts

10 hours. The lethal dose is 100 to 200 milligrams. Examples of incapacitating agents are:

- BZ
- LSD
- LSD Based BZ
- Mescaline
- Psilocybin
- Benzilates

A.2 MEASURES OF TOXICITY

The routes of exposure for chemicals can be one or more of inhalation, ingestion, or absorption through the skin.

Inhalation

In the context of accidental or deliberately engineered releases of toxic chemicals, there are several toxicity indicators. Examples are:

- LC50: the "Lethal Concentration" in air that will prove fatal to 50% of the people exposed to it. This quantity is a function of exposure time. There are other, similar measures, such as the LC10 (10% probability of fatality) and LC01 (1% probability of fatality).
- The probit Pr is a concise summary of the available data on a specific chemical. For a given exposure concentration and duration, there is a chemical-specific equation from which the probit can be calculated. There is then a one-to-one relationship between the value of the probit and the probability that the exposed individual will suffer fatality.
- The Emergency Response Planning Guidelines (ERPGs) are published by the American Industrial Hygiene Association (AIHA). As of 2002, AIHA had published ERPGs for 100 chemicals. There are three levels: (1) ERPG-1—mild irritation; (2) ERPG-2—a threshold for irreversible health effects; and (3) ERPG-3—a threshold for fatalities. Each ERPG is tied to an exposure time of one hour. EPA uses the ERPG-2 or equivalent as the toxic endpoint for hazards analysis in its Risk Management Program.
- Temporary Emergency Exposure Limits (TEELs) are published by DOE for 2234 chemicals at http://tis.eh.doe.gov/web/chem_safety/teel.html. Where ERPGs exist, the TEELs are the same. Otherwise, TEELs are intended to be temporary surrogates for ERPGs.
- Acute Exposure Guideline Limits (AEGLs) are essentially time-dependent ERPGs and are applicable to five emergency exposure periods (10 and 30 min, 1 h, 4 h, and 8 h). A five-minute AEGL is available for some chemicals. The latest information on AEGLS is at http://www.epa.gov/oppt/aegl/chemlist.htm. They are essentially the most current attempts to develop toxicity limits that are useful in the context of emergency response.
  - **AEGL-1** is the airborne concentration (expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3)) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
  - **AEGL-2** is the airborne concentration (in ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, may have irreversible or serious long-lasting health effects, or impaired ability to escape.
  - **AEGL-3** is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Table A-1 displays the relative inhalation toxicity of some of the chemicals mentioned above. The measure provided is the AEGL-2 for one hour, the ERPG-2, or the TEEL-2, depending on which is available.

Dermal Exposure

Some chemicals can produce hazardous health effects by being absorbed through the skin. For example, the blister agent sulfur mustard is specifically designed to do this. As noted above, it is persistent so that people handling contaminated clothing or touching contaminated surfaces can also be affected hours or days after the release. The most effective way in which percutaneous absorption might occur is

TABLE A-1 Relative Measures of Acute Toxicity of Chemical Agents

Chemical	1-hr AEGL-2/ERPG-2/ TEEL-2 (mg/m^3)
Ammonia	105.0
Hydrogen chloride	30.0
Hydrogen Fluoride	16.4
Vinyl Chloride	12.5
Hydrogen Cyanide	11.1
Sodium Cyanide	5.0
Nicotine Sulfate	9.0
Chlorine	7.5
Benzidene	3.5
Chloropicrin	2.0
Parathion	1.0
TEPP	1.0
Phosgene	0.8
Phosphine	0.7
Sulfur Mustard	0.02
Sarin	0.006
VX	0.00027

when there is liquid on the skin. Both sarin and sulfur mustard are effective in this way. In both cases, vapor can also be absorbed through the skin, but this is a much less efficient mechanism.

Ingestion

Both sarin and sulfur mustard can be fatal if ingested. However, on the face of it, this does not seem a promising avenue for a terrorist who wishes to cause large numbers of casualties. It is conceivable that persons whose skin is contaminated by liquid sarin or sulfur mustard could ingest some of the agent, but this particular exposure pathway is not considered further here.

Factors Potentially Influencing Terrorists' Choice of Chemical Agents

All other things being equal, one would choose to use chemicals near the bottom of the Table A-1 for maximum effect. However, there are many other factors that influence the likelihood of successfully achieving terrorist objectives. Examples are as follows:

- The vapor pressure of VX at 20 ºC is 0.00063 mm/Hg. If spilled on the floor, it will evaporate extremely slowly. Sarin is about 20 times less toxic, but its vapor pressure is 1.48 mm/Hg at 20 ºC so that, under given conditions it will evaporate about 200 times more rapidly than VX. Thus, Sarin spilled on the floor of a railcar in the Tokyo Subway attack evaporated rapidly enough to cause fatalities and severe injuries: VX would not have. On the other hand, VX is a persistent agent. If the terrorists' intention had been to cause severe cleanup problems, VX would have been a better choice than sarin.
- Both VX and sarin would be more effectively dispersed if they were aerosolized by some kind of spray device or explosion. Both of them cause severe health effects if absorbed through the skin. Dispersing them as fine droplets in a crowded area would be an effective way of ensuring skin contact. However, building effective aerosolizing devices is more difficult than simply arranging for a liquid to be spilled.
- On its face, chlorine is much less attractive as a potential WMD. Its toxicity as measured by the 1-hr AEGL-2 is one thirty thousandth that of VX. However, chlorine is available in extremely large quantities on the nation's transportation networks (e.g. 90 ton railcars). Its vapor pressure at 20 ºC is approximately 8 atm. When released catastrophically, as explained below, all of the chlorine may well become and remain airborne and cover many square miles with potentially dangerous concentrations within a few minutes. From the terrorist perspective, this could well be attractive. Similar arguments apply even in the case of ammonia, which has the highest of all the toxicity levels in the above table.

In short, the terrorist's choice of a chemical will be driven by several factors:

- Toxicity
- Persistence
- Vapor pressure (i.e., ease of getting airborne)
- Ease of availability or manufacture of the chemical
- Mass available, and (last but not least)
- Objectives (e.g., maximize fatalities, maximize economic disruption, maximize cleanup problems).

A.3 ATMOSPHERIC DISPERSION OF CHEMICAL AGENTS

There is a huge variety of ways in which toxic chemicals can be released and subsequently dispersed in the atmosphere. The following are some examples pertinent to possible terrorist activities in the transportation system.

Gases Liquefied Under Pressure and Transported in Bulk

Ammonia and chlorine are transported as gases liquefied under pressure in amounts up to 90 tons in railcars. The attractiveness of these toxic materials from the terrorist perspective is that it is possible to release large quantities very quickly, as is explained below.

Chlorine

In its usual transportation containers, (150lb or 1 ton cylinders, 17 ton road tankers or 90 ton railcars) chlorine is a gas liquefied under pressure. For example, at 77 ºF (25 ºC) the vapor pressure of chlorine is 8 atm[1]. When the liquid is released, part of it (about 20%) flashes to vapor and the rest can be fragmented into fine liquid droplets. Unless the emerging release encounters an obstacle (e.g. impinges on the ground or adjacent structures), all of the vapor and droplets can remain airborne. If the size of the rupture in the chlorine container is sufficiently large, most if not all of the whole contents can become airborne in a time that varies from virtually at once to a few minutes[2]. Thus, a terrorist could put a large quantity of highly toxic chlorine into the air in a time so short that measures to minimize the release cannot be implemented. As air is entrained, the liquid droplets

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[1] Physical properties of chlorine (vapor pressure, boiling point, flash fraction, fraction of liquid droplets remaining airborne, etc.) obtained from Appendix A of CCPS (1996).

[2] Appendix A of CCPS (1996) calculates the rate of release of chlorine through a hole of diameter 3" in the liquid space of a chlorine vessel at 25 ºC as 44.16 kg/s.~97 lb/s. This would empty a 17 ton road tanker in about 6 minutes. If terrorists used explosives to blow a one-foot diameter hole in the side of the road tanker, the vessel could empty in about 20 seconds.

evaporate. The cloud is denser than air, partly because the molecular weight is 70, partly because the flashing release is initially at the boiling point of chlorine (about –30 °F), and partly because initially entrained air is cooled as it evaporates the droplets.

One characteristic of heavy vapor clouds is an initial slumping phase when they behave much as would a liquid. They become very broad and can even back up against the wind. For 20 ton or 90 ton releases, the backup can be several hundred meters and the cloud can become a kilometer or more [3]in width within a few minutes. Another consequence of the pseudo-liquid-like behavior of heavy vapor clouds is that they will tend to run into depressions, ditches, drains, and basements of buildings (if released in an urban area). They can persist there for several hours if the windspeed is low or if internal volumes are not well ventilated. This can be dangerous for unwary members of the public and emergency rescue personnel.

Once the initial slumping phase is over, during which the chlorine is considerably diluted by air entrained due to turbulence generated within the cloud itself, the vapor begins to behave more like a passive plume in which the predominant dilution mechanism is the entrainment of air by the action of atmospheric turbulence. Conservative atmospheric dispersion models, such as that used by EPA in its guidance on atmospheric dispersion modeling for Risk Management Programs (EPA 1999) as embodied in RMP*Comp (EPA 2004), show that a 17 ton release of chlorine in unfavorable weather conditions can propagate up to 5.8 miles at an urban site or 12 miles at a rural site before falling below the ERPG-2 of 3 ppm. The corresponding distances for a 90 ton railcar are 14 miles and > 25 miles respectively. While it is exceedingly unlikely that such distances will actually be achieved, nevertheless it is entirely possible that a broad chlorine vapor cloud would cover many square miles with concentrations that could prove highly injurious or fatal, and that this could happen within a few minutes.

Anhydrous Ammonia

Anhydrous ammonia is also transported as a gas liquefied under pressure in road tankers or 90 ton railcars. Many people believe that, because ammonia is less dense than air, it will rise when it is released. This is true if the release contains only pure vapor. However, it is well established that sudden, large releases of ammonia from pressurized containment behave in much the same way as do large releases of chlorine. There is an initial flashing phase when typically ~ 20% of the ammonia vaporizes and fragments the remaining liquid. Because the situation is highly turbulent, much air is entrained virtually instantaneously (as much as 10–20 times as much air as the mass of ammonia released). This evaporates the liquid droplets and, within less than a minute, the cloud consists of air at the boiling point of ammonia mixed with a few percent of ammonia. This mixture is heavier than air and slumps as was described for chlorine above, becoming very broad and backing up against the wind (Kaiser 1989)[4].

The principal difference between chlorine and ammonia as an effective means of causing mass casualties lies in the very different levels of toxicity. From Table 7.2.2, the AEGLs for Ammonia are 50–150 times as large as those for chlorine. Therefore, a release of ammonia will propagate to a much smaller distance than would the release of the same mass of chlorine before falling below levels such as AEGL-2 or ERPG-2. This is evidenced by results from RMP*Comp, which show that 17 tons of ammonia would propagate up to 2.1 miles at an urban site or 3.3miles at a rural site before falling below the ERPG-2 of 150 ppm. The corresponding distances for a 90 ton railcar are 4.9 miles and 7.8 miles respectively. As for chlorine, it is extremely unlikely that such conservative distances would actually be realized as a result of an ammonia release. A study (Kaiser et al. 1999) that compiled data from 12 accidental releases of ammonia, including railcars and road tankers (Markham 1986), large-scale anhydrous ammonia release experiments (Goldwire et al. 1985), and dispersion models showed that concentrations of 20,000 ppm (which is the LC50 for durations of cloud passage of a few minutes) are never exceeded beyond a few hundred meters from the point of release. Concentrations in the range 1,000–10,000 ppm are not seen or predicted beyond about 2 km. This observation is pertinent for emergency responders in that, in practice, distances predicted by conservative models with conservative endpoints like those in RMP*Comp are extremely unlikely to be encountered.

Materials That Are Liquids at Typical Ambient Temperatures

Many toxic chemicals have boiling points that are above any reasonably anticipated ambient temperature. For example, sarin has a boiling point of 316.4 °F[5]. Therefore, if spilled, it will initially form a slowly evaporating pool on the ground. For such pools, the subsequent rate of evaporation is limited by mass transfer from the pool to the atmosphere and is dependent on vapor pressure (1.4 mm/Hg at 68 °F ~ 1,800

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[3] For the 3” hole described in footnote 2, Appendix A predicts that the chlorine vapor cloud will be 3.4 km wide at a distance downwind of 1 km in atmospheric stability category F with a windspeed of 2 m/s. However, this predicted width is reduced by a factor of 5 in atmospheric stability category D with a windspeed of 5 m/s.

[4] On May 11 1976, a road tanker carrying 19 metric tons of anhydrous ammonia crashed through a barrier on an elevated section of motorway near Houston, TX. The pressurized tank burst on falling to the roadway below and the contents were rapidly released. (McMullen 1976). After about one minute the observed breadth of the cloud was 400–600m. The maximum upwind distance, measured by observing burnt grass, was 200m. These observations are substantiated by photographs in Fryer and Kaiser (1979). In 1977, a train derailment in Pensacola, Florida punctured the tank head on a rail car so that 50% of the contents, amounting to some 40 metric tons, quickly vaporized. (NTSB, 1978). After about five minutes, the cloud was already “about a mile across.”

[5] Physical data on Sarin from the National Institute of Occupational Safety and Health (NIOSH) Emergency Response Card for Sarin, available at http://www.bt.cdc.gov/agent/sarin/erc107-44-8pr.asp.

ppm), the area within which it is confined or over which it spreads, and the windspeed (CCPS 1996, Section 4.2.5). Sarin is likely to be available to terrorists only in small quantities. For example, on March 20, 1995 a terrorist cult released a few liters of sarin in commuter trains on three different Tokyo subway lines. They concealed the sarin in lunch boxes and soft-drink containers and placed it on subway train floors. It was released as terrorists punctured the containers with umbrellas before leaving the trains so that the sarin spilled onto the floor of the subway cars and began to evaporate (Ohbu et al. 1997). Therefore, it is more likely to be used in an attack on the transportation system than in an open-air release.

In point of fact, pouring agents like sarin and sulfur mustard on the ground or floor is a relatively inefficient way of dispersing them. If terrorists were able to obtain or manufacture chemical munitions, they could cause a more devastating impact. For example, as quoted by Purver (1995) from Berkowitz et al. (1972):

> "In the open, six pounds of Sarin distributed by a three pound burster charge at a height of 15 feet creates a dosage of 3500mg-min/m^3 20 yards from the burst within 10 seconds; in 25 seconds the cloud expands to a 50-yard radius with a minimum dosage of 100 mg/m^3 (Robinson, 1967). A minute after the burst, anyone in an area of over 70,000 square feet around the burst will have received at least a median lethal dose, and probably much more than that. In a confined space (banquet hall, auditorium), the effects will be even greater."

Similar comments about effects could be applied to a confined space such as a crowded airport terminal. The impact would be further enhanced by the use of a persistent agent such as sulfur mustard.

Note that Purver (1995) states that "Chemical weapons such as nerve agents are generally credited with being capable of causing casualties in the range of hundreds to a few thousand." Thus the magnitude of the consequences would not be as great as could potentially be obtained from biological or nuclear weapons.

HVAC Systems

Gases could potentially be introduced into the HVAC systems of large buildings such as airport terminals or large vessels such as passenger liners. For example, it might be possible to release the contents of a 150 lb cylinder of chlorine into the HVAC intake. It would also be possible to envisage pouring the contents of a container of sarin the size of a milk bottle into the HVAC system.

Releases into or onto Water

As an example of potential terrorist interest in the transportation of toxic chemicals, consider the transportation of anhydrous ammonia by barge. This occurs extensively on inland and coastal waterways in the U.S. in barges typically containing 2,500 tons of refrigerated liquid ammonia. If the tanks containing this ammonia were to be ruptured (perhaps by a USS Cole-type attack), up to 40% of the refrigerated ammonia could be vaporized (Raj et al. 1974). What happens is that, as ammonia dissolves in the water, heat is released, which is responsible for vaporizing the aforementioned 40%. Raj et al. also show that the resulting vapor cloud is slightly buoyant (i.e., the liquid droplet effects described for the pressurized release are not important in this instance). However, this does appear to be a potential mechanism for rapidly vaporizing up to a thousand tons of ammonia.

A.4 METHODS FOR INTRODUCING AND DISPERSING CHEMICALS

The means of maliciously introducing and dispersing chemical agents discussed above can be summarized as follows:

- Hijack a railcar or road tanker of chlorine or ammonia, move it to an optimum location and rupture the containment with an explosion. Within a short time, an area potentially encompassing many square miles could be covered by a vapor cloud that is potentially dangerous or fatal to those exposed.
- Cause a highly toxic chemical such as sarin to be spilled in a confined space such as a subway car. It will evaporate and cause adverse or fatal health effects through inhalation.
- Obtain a chemical munition containing an agent such as sarin and explode it in a large confined volume such as an airport terminal. Individuals would be affected both through inhalation and by liquid droplets impinging on exposed skin. The adverse consequences could be enhanced by using a persistent agent such as sulfur mustard whereby surfaces would be dangerously contaminated by deposited liquid for hours or days.
- Introduce a toxic gas into the HVAC system of a building such as an airport or marine terminal, or the HVAC system of a ship.
- Hijack and blow up a barge or ship containing a large quantity of material such as ammonia.

Note that these are only meant to be examples of a much larger number of scenarios that can be imagined.

A.5 EXAMPLES OF CHEMICAL INCIDENTS

The following subsections provide summaries of chemical events that are examples of the potential effects of a terrorist attack using a chemical agent. Some of the summarized events are hypothetical, most are actual accidents that have occurred. These examples are grouped as: chemical weapons events, chemical transportation incidents, and releases from fixed facilities.

A.5.1 Chemical Weapons Events

The following are examples of actual or potential attacks on transportation systems.

The Tokyo Subway Attack—Sarin

The most notorious chemical attack on an element of the transportation system was the use of sarin in an assault on the Tokyo subway system on March 20, 1995[6]. Members of a Japanese millenarian cult, Aum Shinrikyo released sarin gas on several lines of the Tokyo subway. As a result, 12 people died and thousands were injured.

Aum Shinrikyo was a Japanese millenarian cult centered on the charismatic leader Asahara Skoko, whose teachings combined elements of Buddhism and Hinduism as well as millenarian Christianity. Central to the group's teachings is that the apocalypse is near. The Aum cult attracted people from all walks of life, and had as many as 10,000 followers at its peak. Members lived in communes, cut off relations with outsiders, and gave all their savings to the cult. It was believed that the cult was to become more powerful than the state, and needed the most advanced weapons of mass destruction to achieve this end.

Monday, 20 March, 1995 was for most a normal workday, though the following day was a national holiday. The attack came at the peak of the Monday morning rush hour on one of the world's busiest commuter transport systems. The liquid sarin was contained in plastic bags which each team then wrapped in newspapers. Each of the five perpetrators carried two packets of sarin totaling approximately 1 liter of sarin, except for one who carried three bags. Thus, there was a total of only about 5 liters used in the attack. A single drop of pure sarin the size of the head of a pin can kill an adult. However the sarin used was diluted, possibly to cause slower effects and thereby allow more people to be exposed.

Carrying their packets of sarin and umbrellas with sharpened tips, the perpetrators boarded their appointed trains; at prearranged stations, each perpetrator dropped his package and punctured it several times with the sharpened tip of his umbrella before escaping to his accomplice's waiting getaway car. The Tokyo subway system transports millions of passengers daily. During rush hour trains are frequently so crowded that it is impossible to move.

As noted above, 12 people were killed in the attacks. Symptoms included choking, coughing, foaming at the mouth, and fading vision as victims staggered from the trains. Those that received the highest doses fell to the ground, writhing in convulsions. At one subway station in particular, the subway entrance was described as resembling a battlefield, where the injured simply lay on the ground, struggling for breath. In other areas, many of those affected by sarin went to work in spite of their symptoms. Most of these left and sought medical treatment as the symptoms worsened. Several of those affected were exposed to sarin only by helping passengers from the trains (these include passengers on other trains, subway workers and health care workers). Recent surveys of the victims show that many are still suffering, particularly from post-traumatic stress disorder. In one survey, 20% of 837 respondents complained that they feel insecure whenever riding a train, while 10 percent answered that they try to avoid any gas-attack related news. Over 60 percent reported chronic eyestrain and said their vision has worsened (Mainichi Online 2001).

Purver (1995) provides a detailed review of the then-current information about the subway attack. He suggests that Aum Shinrikyo experimented with poison gas before March 20, 1995. For example, in the mountain resort of Matsumoto, 125 miles northwest of Tokyo, late in the evening of 27 June 1994, a substance later identified as sarin seeped through the open windows of apartments and houses, killing or injuring every living thing inside an area 500 yards long by 100 yards wide. Seven people were killed and 264 sought hospital treatment. A report in the London Sunday Times of 19 March 1995 (just one day before the subway attack) reported that there had been "an intensive investigation involving a special sarin unit of Tokyo's metropolitan police department criminal investigation laboratory, the national police agency, and the security services that had concluded that "the attack was a trial run by terrorists of the delivery system" of a chemical agent.

Purver also indicated that commentators expressed surprise that, given the toxicity of sarin and the nature of the target, the casualty toll had not been much higher. Had the terrorists implemented a means of aerosolizing the sarin, rather than simply letting it evaporate from the floor of the subway cars, many more people would have been killed, although the rapidly falling bodies would have prevented others from entering the train, thus possibly exposing fewer people to the sarin. Police raids on Aum Shinrikyo compounds uncovered the capacity to make much larger quantities of sarin, other agents such as tabun (which is ten times as toxic as sarin), evidence of experimentation with biological weapons including botulism, and evidence of attempts to obtain the Ebola virus and Q-fever.

An Aborted Attack on the Tokyo Subway—Hydrogen Cyanide

On Friday May 5, 1995, Tokyo subway guards responded to a fire in a public restroom, and averted a potential mass-casualty incident (Purver 1995). The incident it attributed to Aum Shinrikyo cult. Two plastic bags, one containing two liters of powdered sodium cyanide already in flames and the other containing 1.5 liters of diluted sulphuric acid, were found side-by-side on the floor of a men's bathroom in Tokyo's busiest subway station, Shinjuku. The bags reportedly were arranged so that a reaction producing hydrogen cyanide gas would have occurred if contents from the two bags had mixed.

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[6] The primary source for this summary, except as otherwise noted, is "Protecting Public Surface Transportation Against Terrorism and Serious Crime: Continuing Research and Best Security Practices," published by the Mineta Transportation Institute (2001), and available at. http://www.transweb.sjsu.edu/publications/terrorism_final.pdf.

Four subway guards who doused the flames with water were overcome by fumes and briefly hospitalized, but otherwise there were no casualties. Chemical experts later estimated that the amount of cyanide gas that could have been released may have been sufficient to kill between 10,000 and 20,000 people.

Hypothetical Scenario—Persistent Agent

Several workers move drums labeled as cleaning agents into a large shopping mall, large public facility, subway, train station, or airport. They dress as cleaners and are wearing what appear to be commercial dust filters or have taken the antidote for the agent they will use. They mix the feedstocks for a persistent chemical agent at the site during a peak traffic period. Large-scale casualties result, and draconian security measures become necessary on a national level. A series of small attacks using similar "binary" agents virtually paralyze the economy, and detection is impossible except to identify all canisters of liquid (Cordesman 1996).

A.5.2 Chemical Transportation Incidents

Bulk chemicals are transported by truck, rail, barge, and ocean-going vessels. For chemicals categorized as "toxic by inhalation", 59% of the annually transported tonnage moves by rail, amounting to 5,766,000 tons. Based on ton-miles, a much larger proportion of chemicals (i.e., 95% or, 4,940x10^6 ton-miles) are transported by rail (GAO, 2003a). To exemplify the variety of hazardous bulk chemicals shipped in the US, Table A-2 shows the volumes of hazardous materials shipped by rail from 1998–2001. The authors are unaware of any deliberate, large-scale release of a highly toxic chemical from the transportation system. The scenarios presented after Table A-2 are examples of accidental releases that could potentially be replicated by terrorists.

Ammonia Release from Road Tank Truck—Houston, TX

Between 11.09 am and 11.15 am on May 11, 1976, a tank truck crashed through a guard rail at the Southwest Freeway and Loop 610 West Interchange, landing on a street some 30 feet below. The tank ruptured on impact, releasing 19 tons of anhydrous ammonia. The accident resulted in the immediate death of four people and injury to more than one-hundred others. Two other victims died later as a result of their injuries. (McMullen, 1976). One of the most striking features of this accident was that the ammonia cloud exhibited

TABLE A-2 The Top 20 Hazardous Materials Shipped by Rail By Volume 1998–2001[a]

Hazardous Material	Estimated Total Carloads, 1998-2001[b]	Estimated Annual Average No. of Carloads
Freight Forwarder Traffic[c]	1,188,109	297,027
All freight rate shipments, not elsewhere coded (NEC) or trailer on flatcar shipments, commercial, except where identified by commodity.	716,177	179,044
Sulfur liquid or molten nonmetallic minerals except fuels	273,005	68,251
Liquefied Petroleum Gas, NEC, compressed	253,234	63,308
Sodium (soda), caustic (sodium hydroxide)	236,455	59,114
Asphalt pitches or tars, from petroleum, coal tar, coke ovens, or natural gas	222,163	55,541
Sulfuric acid or oil of vitriol	200,875	50,219
Anhydrous ammonia	163,057	40,764
Chlorine	128,600	32,150
Gasolines, blended, consisting of motor fuels containing 50% or more of gasoline	97,192	24,298
Ethyl alcohol, anhydrous denatured in part with petroleum products and/or chemicals (not to exceed 5 wt%)	95,333	23,833
Phosphate fertilizer solution, containing not more than 77 wt% of phosphoric anhydride	90,779	22,695
Chemical, NEC	86,854	21,713
Vinyl Chloride (chloroethane or chloroethylene)	73,033	18,258
Methanol (methyl or wood alcohol liquid)	67,903	16,976
Propane gas, liquefied	65,702	16,425
Carbon dioxide gas, liquefied or carboic acid gas	63,020	15,755
Ammonium nitrate fertilizer	62,563	15,641
Muriatic (hydrochloric) acid	58,165	14,541
Styrene (liquid)	55,910	13,977

Footnotes for Table A-1

a. Reproduced from GAO (2003a), Appendix III, Table 4

b. Extrapolated from a 1% sample of waybills

c. Non-bulk, mixed

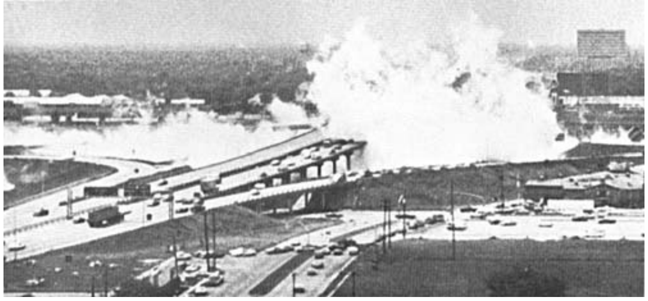

Figure A-1. Cloud of ammonia fumes spreading over the west loop 610 overpass, Houston, TX, May 11, 1976. Photo reproduced from Fryer and Kaiser (1979). Photograph taken by Carrol S. Grevemberg.

the ground-hugging features of a dense vapor cloud. Figure A-1 was taken about a minute after the after the crash from the Transco tower in the Houston Galleria complex.

One can see that as the vapor cloud propagates downwind (from right to left), it appears to decrease in height. This is characteristic of a slumping, heavy vapor cloud. In addition, the cloud is backing up against the wind towards the right of the picture. This is reinforced by Figure A-2, which was taken from a Houston Air Pollution Control Program Enforcement helicopter after the ammonia had dispersed.

The photograph shows the area where the grass had been burnt by the ammonia. The wind was blowing from left to right. One can clearly see that the plume spread a considerable distance both across the wind and upwind. The upwind boundary is at about 200m and the cloud is about 600m across just downwind of the overpass (Kaiser 1979).

As was briefly discussed above, it is well established that sudden, large releases of ammonia from pressurized containment behave as denser-than-air vapor clouds. There is an initial flashing phase when typically ~ 20% of the ammonia vaporizes and fragments the remaining liquid. Because the situation is highly turbulent, much air is entrained virtually instantaneously (as much as 10–20 times as much air as the mass of ammonia released). This evaporates the liquid droplets and, within less than a minute, the cloud consists of air at the boiling point of ammonia mixed with a few percent of ammonia. This mixture is heavier than air (Haddock and Williams 1978) and slumps as was described for chlorine above, becoming very broad and backing up against the wind (Kaiser 1989).

Figure A-2. Photo of the Houston ammonia tank truck crash site after the ammonia had dispersed.

Depending on the weather conditions and the amount of ammonia released, the vapor cloud can be considerably larger than that observed in Houston. See the discussion of the Pensacola accident below for an example.

This incident is also relevant to potential large-scale deliberate or accidental releases of chlorine. In fact, McMullen (1976) explicitly states “Had the truck been loaded with chlorine______the potential for disaster would be further compounded.” To the authors’ knowledge, there has not been a large chlorine spillage during transportation that has resulted in the immediate or near-immediate release of the contents of the transportation vessel and which resulted in reasonably good documentation of the size of the vapor cloud. However, there is no doubt that chlorine would behave in much the same way as ammonia. If anything, the slumping effects for chlorine would be even greater because chlorine, even as a pure vapor, is already denser than air. Section 7.1.2.4 cites a calculation Appendix A of CCPS (1996) calculates the rate of release of chlorine through a hole of diameter 3” in the liquid space of a chlorine vessel at 25 °C as 44.16 kg/s.~97 lb/s. This would empty a 17 ton road tanker in about 6 minutes[7]. Appendix A predicts that the chlorine vapor cloud will be 3.4 km wide at a distance downwind of 1 km in atmospheric stability category F with a windspeed of 2 m/s[8].

Ammonia Release from Railcar—Pensacola

About 6.06 pm on November 9, 1977, 2 SD-45 locomotives and 35 cars of Louisville and Nashville freight train No. 407 derailed at Pensacola, Florida (NTSB 1978). The adjacent tank heads of the 18th and 19th cars were punctured and this released anhydrous ammonia into the atmosphere. Two persons died and 43 were injured.

NTSB established that, within ten minutes, about 50 percent of the contents of the 19th car quickly vaporized, so that about 40 tons became airborne. The air traffic controller at the Pensacola Airport first observed the ammonia cloud on radar at about 6.10 pm (i.e., only 4 minutes after the accident). At that time, “It appeared to be about one mile in diameter and about 125 feet high.” This substantiated the statement, made above, that clouds that are considerably broader than that observed in the aftermath of the Houston road tanker crash are possible.

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[7] If terrorists used explosives to blow a one-foot diameter hole in the side of a 17-ton road tanker, the vessel could empty in about 20 seconds.

[8] Note, however, that this predicted width is reduced by a factor of 5 in atmospheric stability category D with a windspeed of 5 m/s.

Other Ammonia Transportation Accidents

Crete, Nebraska, February 18, 1969: At about 6.30 am on February 18, 1969, Chicago, Burlington, and Quincy (CB&Q) train No. 64 derailed the 72nd to the 90th cars as the train was entering Crete, Nebraska (NTSB, 1971). The derailed cars struck Train 824, standing on a track north of the main track. A tank car in train 824 was completely fractured by the impact and rapidly released 29,200 gallons (about 76 metric tons) to the atmosphere. NTSB states that "A cloud was formed which blanketed the immediate area. The cloud extended westward beyond the (nearby) Blue River and for several blocks north and south of the railroad. The concentrated cloud of ammonia vapor was retained in the area for a considerable period of time. Unfortunately, the NTSB report provides no further data on the size of the cloud. Three trespassers riding on rain 64 were killed as a result of the derailment. Six people were killed and 53 were injured as a result of exposure to the ammonia cloud. The ambient temperature was 4 °F and the wind was calm.

Minot, North Dakota, January 18, 2002: On January 18, 2002, a 112-car train derailed one mile west of Minot, ND in the Souris River valley. Eleven anhydrous ammonia cars and two granular urea cars released their contents. In excess of 300,000 pounds (about 136 metric tons) of anhydrous ammonia was released from the ruptured tanker cars. One tanker car was propelled over 600 feet in the air and skidded another 500 feet on the ground, crashing through a corner of a nearby house. Part of another tanker car landed on the ice of the Souris River. A dense anhydrous ammonia cloud drifted through low-lying areas of the city. A temperature inversion, with sub-zero temperatures and no wind, prevented the cloud from dissipating. One fatality occurred, 15 people were hospitalized, and eventually over 1600 people sought medical treatment for anhydrous ammonia exposure (Radig 2003). GAO (2003a) states that the vapor plume was 5 miles long and 21/2 miles wide. It caused 1 death and more than 300 injuries and affected 15,000 people. This was in a relatively lightly populated rural area. NTSB has not yet released its report on this accident.

Chlorine Release from Railcar—Mississauga

Just before midnight on Saturday, November 10, 1979, a derailment occurred involving 24 railway tanker cars of a 106-car Canadian Pacific Railway Train in the city of Mississauga, Ontario. One railcar containing 90 tons of liquid chlorine began to leak. More than 200,000 Mississauga residents were evacuated for their protection against potentially harmful exposure to chlorine drifting away from the site, and as a precaution against the possibility of further explosions, which might have released more chlorine. (SCIEX 1980).

SCIEX performed numerous measurements of airborne chlorine concentrations from November 11, 1979 at 1 pm until 10 am on November 19 at numerous locations ranging from about 0.5 km to 5 km from the point of release. The highest recorded concentrations were about 400 $\mu g/m^3$ and the most serious health effects noted were "Eye irritation in plume." For comparison, the chlorine AEGL-2 for a 1-hour exposure is 2 ppm (6,000 $\mu g/m^3$—see Table 7.2.2). No chlorine concentrations above 1 $\mu g/m^3$ were observed after 8 am on November 15.

It is apparent that the chlorine was leaking slowly over a period of days. Thus, the Mississauga derailment and subsequent chlorine leak is not an example of a catastrophic release that might be engineered by a terrorist, although presumably a terrorist would be gratified by the dislocation caused by the need to evacuate nearly a quarter of a million people for several days.

Howard Street Tunnel Fire—Baltimore, MD

At 3:04 pm on Wednesday, July 18, 2001, the 60-car CSX freight train L412-16 entered the Howard Street Tunnel in downtown Baltimore, MD (Carter et al. 2002)[9]. The train carried 29 loaded and 31 empty cars, including several tanker cars. At 3.07 pm, the train lurched and came to a rough stop as several cars derailed. The engineers uncoupled the three diesel engines and exited the tunnel in order to report the event. From the amount of smoke exiting the tunnel, it was clear that there was a fire somewhere among the cars.

Baltimore City firefighters received notification of the event between 3.35 pm and 4.15 pm. After reviewing the bill of lading firefighters discovered that the freight train was carrying a variety of hazardous materials including tripropylene and hydrochloric acid.

One of the immediate problems was to determine the potential environmental impact from the hazardous materials and whether downtown Baltimore needed to be evacuated. This problem was solved by the Maryland Department of the Environment's (MDE's) Emergency Response Division (ERD). Following a review of the bill of lading, ERD personnel contacted members of the South Baltimore Industrial Aid Plan (SBIMAP), a voluntary consortium of manufacturers, emergency response personnel, Baltimore City environmental and emergency management personnel, and MDE. SBIMAP provided two chemists, who quickly determined that, individually or in combination, the hazardous chemicals involved in the fire would not present a serious environmental hazard and that it was not necessary to evacuate downtown Baltimore.

At 10.30 am on July 19, 2001, firefighters found small leaks in one of the hydrochloric acid cars. This necessitated the arrangement of acid transfer activities. The damaged HCl car was finally removed from the tunnel at 11.30 am on July 22. This incident, like the one at Mississauga, is thus more notable for the disruption it caused over a period of several days and the indications it gives of the potential danger. Had there been a car load of chlorine and had the crash caused a significant rupture, the released chlorine would have flowed down the 4.8% grade of the tunnel and poured out into downtown Baltimore. This accident is interesting because of its

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[9] This description of the Howard Street Tunnel derailment draws freely upon and quotes from the work by Carter et al. (2002).

effects on transportation systems in and around Baltimore. It had a major effect on rail transportation, road transportation and transit. It had some effect on marine transportation (the inner harbor was briefly closed to traffic) and some effect on air (to the extent that transportation to and from BWI airport was affected. These are documented by Carter et al. (2002).

The short-term transportation impacts of the July 18, 2001 Howard Street Tunnel fire lasted up to 36 hours and included the following:

Closing of Major Highways into Baltimore: at the request of the Incident Commander, Maryland State authorities closed major highways into the city, including I-83 southbound, MD-295 northbound (the Baltimore-Washington Parkway), Route 40 eastbound and I-395 northbound. These roadways were reopened on the morning of July 19.

Closing of City Streets in the Vicinity of the Tunnel and the Rerouting of Passenger, Bus, and Commercial Vehicle Traffic: Howard Street and the surrounding area were closed to traffic, cutting Baltimore's central business district in half and closing off east-west traffic flows (Howard Street runs North-South for 1.7 miles over the tunnel). This resulted in gridlock, but once traffic management was put in place the City was cleared of traffic within 2 hours of the normal end of rush hour (8pm instead of 6pm).

Closing of the Metro Subway's State Center Station: the station was closed due to smoke accumulation from the fire. However, Metro officials conducted an inspection of the Metro tunnel running under the Howard Street tunnel and determined that no damage had occurred. They were able to keep the trains running. The State Center Station itself was reopened on July 21, 2001.

The Disruption of Light Rail Service: light rail track runs along Howard Street. In the immediate vicinity of the fire a water main ruptured and washed away the track bed, necessitating the closure of the light rail service. Metro set up a bus bridge between nearby stations to carry passengers around the break.

The Disruption of Maryland Commuter (MARC) rail and Oriole Game Day Service: MARC trains were stopped at the Dorsey Station near BWI Airport and bus bridge was set up by the MTA to bring passengers into the city. The bus bridge was only needed for July 18. 2,000 Orioles employees and between 2,500 and 5,000 fans were evacuated.

The Disruption of Bus Services: disruptions were system-wide.

The Closing of the Inner Harbor: the U.S. Coastguard (USCG) closed the inner harbor to boat traffic at 5.00 pm and set up booms to minimize potential contamination from chemicals seeping from leaking rail cars.

The Disruption of Rail Freight Along the East Coast: the Howard Street Tunnel is one of only two direct northeast-southeast freight lines along the East Coast. Losing access to the tunnel required CSX to divert or delay a significant portion of rail traffic along the Eastern Seaboard. Freight moving from the northeast to Florida was advised to expect delays of 24 to 36 hours. Some freight that would normally have used the tunnel was diverted as far west as Ohio.

Medium-term transportation impacts of the July 18, 2001 Howard Street Tunnel fire continued until July 19 to 23, 2001. These impacts included the following:

Suppression of and Initial Clean-up from the Tunnel Fire took approximately 5 days. All cars were removed from the tunnel and inspected for damage, and all hazardous materials were off-loaded and removed. The tunnel was inspected for structural damage and reopened to rail traffic on July 23.

Miscellaneous: On Monday morning, July 23, when city and state employees returned to work after taking advantage of liberal leave at the end of the previous week, traffic was backed up for more than a mile on northbound I-95 before the junction with thI-395 spur that takes traffic downtown. Street closures in the vicinity of Howard and Lombard Streets caused MTA officials to divert approximately 23 bus routes. Light rail service continued to rely on buses to transport riders between the Patapsco and North Avenue Station stops around the section of track damaged by the water main break. For five days following the accident, streets in the vicinity of the tunnel and the water main break remained closed, and all vehicle traffic was diverted. On July 24, nearly all of the streets were reopened to traffic. Only a two-block stretch of Howard Street and a portion of Lombard Street remained closed.

Metro: commuters took advantage of Metro services to travel into Baltimore during this time. Ridership on Monday July 24 was 7,000 higher than normal.

East Coast Rail Network: the East Coast network became increasingly constrained with each day that the major north-south artery through the Howard Street tunnel remained closed. Freight trains were delayed, cancelled, or diverted hundreds of miles throughout the Middle Atlantic States.

MARC Rail Service on the Camden Line was also disrupted until the fire was suppressed. Service ended at the Dorsey Street Station near BWI airport. However, there was not a significant decrease in ridership because MARC commuters to and from Washington D.C. took advantage of free parking at the Dorsey Street station.

Longer-term transportation impacts of the July 18, 2001 Howard Street Tunnel fire included only the 55 days it took to repair the damage to the Central Light Rail Line caused by the bursting water main. Relatively speaking, there were no long-term impacts as might have been the case in the event of a radiological incident.

Table A-3 summarizes the agencies that were involved and their roles and responsibilities.

A.5.3 Releases from Fixed Installations

There is a vast range of releases of toxic chemicals from fixed installations. The following are a couple of examples.

TABLE A-3 Incident Response and Agency Responsibilities (Table 5 from Carter et al 2000)

Jurisdiction	Modal Administration or Agency	Role in Incident Response	Area of Concern
Baltimore City	Fire Department	Incident Command	Fire Suppression.
	Police Department	Traffic Enforcement	Closing of streets crossing over the Howard Street Tunnel.
	Department of Public Works	Infrastructure Repairs Traffic Management	Repairs to water main and street surface at Howard and Lombard Streets. Traffic control in Baltimore.
	Office of Emergency Management	Interagency Coordination & Public Information	Media information.
Maryland Department of Transportation	Headquarters	Coordination of DOT Response Activities	Worked with Baltimore Department of Public Works (DPW) to establish a plan on how to repair the infrastructure damage once the fire was extinguished (procurement issues–having a contractor in place, developing a plan on how repair work would be implemented once the "green light" was received, plans for site survey, traffic diversion, etc.).
	State Highway Administration	Traffic Management on Interstate System	Through CHART system[10], posted notices on fixed and mobile DMS advising that major routes into the city were closed.
	Mass Transit Administration	Rail and Bus Transit Operations in Baltimore City	Light rail and bus operations. Establishing bus bridge between north and south segments of light rail. MARC operations. Metro subway operations–tunnel inspection.
	Maryland Transportation Authority	Traffic management on I-95 approaches to Ft. McHenry Tunnel & I-395	Ensured that I-395 route into Baltimore was closed off during initial incident response activities.
Maryland Department of the Environment (MDE)	Emergency Response Division	Air Quality, Water Quality, Hazardous Materials, Leaks/Discharges	Obtained information possible environmental impact of train fire (hazardous materials). Monitored air and water quality in area around the tunnel and the Inner Harbor. Checked railcars pulled from tunnel for structural integrity. Coordinated removal and disposal of hazardous materials from the train.
Maryland Emergency Management Agency	N/A	Coordination of State Government Emergency response and Incident Management Activities	Coordinating activities of state agencies. Media relations and rumor control.
U.S. Coast Guard (USCG)	USDOT	Supported MDEI	Implemented waterway safety measures, including closing of Inner Harbor. Supported hazardous material detection and containment.
U.S. Environmental Protection Agency (EPA)	N/A	Supported MDE	Assisted with monitoring of air quality and water

Methyl Isocyanate Release—Bhopal

The Union Carbide India Ltd. (UCIL) pesticide plant in Bhopal, India produced Methyl Isocyanate (MIC) by reacting monomethylamine with phosgene in the plant's MIC production unit. The MIC was used to make SEVIN carbaryl and several other carbamate pesticides. The MIC was stored in two horizontal, mounded, 15,000-gallon, stainless steel tanks. On the night of December 2–3, 1984, the 41 metric tons of MIC in one of the tanks underwent a chemical reaction which was caused by the introduction of water into the tank (Kalelkar 1988). A toxic cloud of MIC drifted over the hundreds of dwellings in a crowded shanty town outside the plant, killing more than 3,800 people and leaving 11,000 more with permanent disabilities (figures provided by the Indian Government in 1991). Investigations proved that the introduction of water was deliberate (Browning 1993).

Once the toxic cloud had dispersed and drifted away, there appeared to be no lasting impact on transportation systems around the plant. The water was introduced by a disgruntled employee who may not have been aware that the consequences would be so catastrophic. However, it does illustrate the potential for terrorists to work with an insider to engineer catastrophic releases of toxic chemicals.

Hydrogen Fluoride Release—Texas City

At 5.20 pm on October 30, 1987, a crane was moving a 50-foot, multi-ton convection section from a vertical heating

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[10] The CHART (Chesapeake Highways Advisories Routing Traffic) program started in the mid-1980s as the "Reach the Beach" initiative, focused on improving travel to and from Maryland's eastern shore. It has become so successful that it is now a multi-jurisdictional and multi-disciplinary program extending statewide. This comprehensive, advanced traffic management system is enhanced by a newly constructed state-of-the-art command and control center called the Statewide Operations Center (SOC). The SOC is the "hub" of the CHART system, functioning 24 hours-a-day, seven days a week with satellite Traffic Operations Centers (TOCs) spread across the state to handle peak-period traffic.

vessel to a semi-truck trailer in Marathon Petroleum Company's Texas City refinery. The crane was located immediately east of the HF acid vessel, which was part of the plant's HF alkylation unit. The crane dropped the convection section while it was above the HF vessel (Ryan 1988). The convection section severed two lines attached to the HF vessel. Marathon reported that 53,200 pounds of HF were released over a 44-hour period. Shortly after the accident, Marathon directed a water spray at the HF cloud.

As of November 16, 1987, local area hospital reported a total of 1,037 patients who were treated for HF exposure. Of these, 97 were hospitalized, two of whom were in critical condition. There were no fatalities. 85 square blocks and approximately 4,000 residents were evacuated.

Reports of the incident do not indicate that the HF cloud hampered the activities of emergency responders.

A.6 CHEMICAL DETECTION

Chemical detection equipment (CDE) is an essential component of hazardous material (HAZMAT) emergency response. This equipment should detect the harmful agent, correctly identify the agent, and define the area of exposure. Rapid detection is essential so that responders and military targets can recognize a threat and don protective gear (ideally in <9 s). It also is important to know the extent of contamination. During several documented chemical attacks, first responder casualties have been vast enough to delay the rescue. During the Tokyo subway sarin attack in 1995, 9% of emergency medical services (EMS) providers suffered the affects of acute exposure. Effective CDE may help prevent these occurrences.

Several different technologies are used today to detect chemical agents (CAs). CAs are defined as chemicals intended to kill or seriously injure human beings. CDE usually detects the most common CAs: nerve agents, blister agents, and arsenical vesicants. A large variety of equipment is available that is capable of identifying liquid droplets of CAs on surfaces and in vapors. Laboratory-based equipment can detect agents in water. The main challenges with these technologies are ensuring an appropriate sample for analysis and filtering out nonhazardous environmental chemicals that may be present. This article focuses on the technologies and devices that may be used by first responder teams in the field. Laboratory detection techniques are beyond the scope of this discussion.

Chemical Detection Paper

Chemical detection paper is a very sensitive technique for detecting CAs. It is one of the least sophisticated and thus least expensive methods of detection. It is used to detect liquids and aerosols and is a common means for defining a contaminated area. Chemical detection paper is composed of 2 dyes soluble in CAs and a pH indicator integrated into cellulose fibers. When exposed to CAs, it can change color according to the type of agent. If an aerosolized droplet encounters the paper, the diameter and density of the spot can be used to determine the droplet size of the agent and the degree of contamination.

Chemical detection paper lacks specificity and is prone to error because it reacts with contaminants such as brake fluid, antifreeze, and insect repellent, resulting in false-positive readings. False readings are especially undesirable in civilian situations because they may lead to mass panic. Therefore, chemical detection paper should always be used with another modality for accuracy of detection.

M8/M9 chemical detection paper

M8 and M9 CA detection papers, commonly used by the military, are available commercially to HAZMAT response teams. M8 paper is packaged in 25 perforated sheets, 2.5 in by 4 in, and is blotted on liquids that arouse suspicion. It identifies CAs by changing colors within 30 seconds of exposure: dark green for vesicants, yellow for nerve agents, and red for blister agents.

M9 paper has adhesive backing that allows it to be attached to clothing and equipment. M9 paper detects the same agents as M8 paper but does not change color to enable identification. M9 paper tends to react faster than M8 paper and can be attached to vehicles that are entering areas filled with vapor to determine contamination. Vehicles thus equipped are limited to a speed of 30 km/h.

M256A1 chemical agent detection kit

The M256 CA detector kit originally was released in 1978 and was modified in 1987 to the M256A1, which is sensitive to lower concentrations of nerve agents. It was used extensively during the Gulf War but also is available commercially. It is another common component of CDE provided to civilian response teams. This portable kit detects nerve gas, mustard gas, and cyanide and usually is used to define areas of contamination. The M256A1 contains a package of M8 paper, detailed instructions, and a vapor sampler (12 enzymatic tickets that contain laboratory filter paper for detecting CA vapors). The vapor sampler employs wet chemistry technology, in which ampoules containing different substrates are crushed so that the liquids interact with strips of filter paper, chromatographic media, and glass fiber filter. These substrates then are exposed to the vapor under suspicion. The reaction causes a color change, alerting the user to the presence of a CA. The reactions typically take 15 minutes to occur.

The M256A1 can detect nerve gas concentrations of 0.005 mg/m^3, hydrogen cyanide concentrations of $11 mg/m^3$, and mustard gas concentrations of 0.02 mg/m^3. This is one of the military's most sensitive devices for detecting CAs and detects all agents at levels below those that can kill or injure people. It is prone to false-positive results, similar to other enzymatic detection techniques, but has not been demonstrated to produce false-negative results in real situations.

Colorimetric tubes

Colorimetric tubes such as those available from Draeger and RAE systems use enzymatic techniques to identify CAs. A hand pump is used to draw a sample into a specific tube, and the concentration of the substance is read from the tube. This is another simple and inexpensive way of detecting and identifying a CA. It is used extensively in civilian response units for this reason, but it has some disadvantages. Available are 160 substance-specific reagent tubes identifying different agents. For each agent, a different tube must be used. Efficient use of this system demands knowledge of which CA is likely to be present in a given environment. If a tube for vesicants is used to sample the air and the CA is a nerve agent, the tube reports a false-negative result. A tube for each possible CA must be used for thorough detection.

Ion Mobility Spectroscopy

Ion mobility spectroscopy (IMS) is used in many handheld and stand-alone detection devices that can be used to scan equipment, surfaces, and people for contamination. This technology involves drawing a gaseous sample into a reaction chamber using an air pump. The air molecules then are ionized, most commonly using radioactive beta emitters such as nickel-63 or americium-241. The ionized particles then are passed through a weak electrical field toward an ion detector. Contaminants are identified according to the time it takes to traverse the distance to the detector. This time is proportional to the mass of the molecule. The pattern is compared to a sample of clean air; if the pattern is markedly different and unique to certain types of agents, the alarm sounds. These systems are capable of detecting and distinguishing between nerve gas, mustard gas, and vesicants. Its sensitivity ranges from 0.03 mg/m^3 for nerve gases such as sarin to 0.1 mg/m^3 for mustard gas.

IMS has certain advantages. It is less sensitive to contaminants, because it relies on a clean air sample for calibration. Thus, if an area has a certain baseline nonhazardous environmental vapor present, it is not detected.

Stand-alone detectors—M8A1, Automatic Chemical Agent Alarm, and Fixed Site/Remote Chemical Agent Detector

Many stand-alone detectors also use IMS technology. The military employs the M8A1 detector that consists of a stand-alone detector, which continuously monitors the environment for hazardous vapors and aerosols, and up to 5 alarms that can be dispersed throughout an area. The M8A1 detects nerve agents and blister agents when the concentration is 0.1 mg/m^3 or greater and alarms within 1–2 minutes. M8A1 is an ideal device for protection from off-target attacks, in which a vapor is released upwind from the targets. However, it is less effective for on-target attacks, in which the CA is released in large amounts within seconds. In this situation, the alarm sounds after the personnel have been exposed. This system was used during the Gulf War and has been upgraded to the Automatic Chemical Agent Alarm (ACAA) system. The ACAA is slightly larger and has a communications interface that is useful in combat.

ETG provides a commercial version of an IMS stand-alone detector called the Fixed Site/Remote Chemical Agent Detector. This system detects and identifies nerve and blister agents and offers superior reliability from interference. The alarm information can be transmitted via radio, satellite, or hardwiring. This system can be useful if placed in hospital wards or at victim collection sites to detect contamination

Infrared Detection

Infrared radiation (IR) is employed in several CA detectors, including long-range detectors and point detectors. IR can be used to excite molecules, and each agent has a unique infrared pattern referred to as a fingerprint. Several different detection techniques use IR, including photoacoustic infrared spectroscopy, filter-based infrared spectroscopy, forward-looking infrared spectroscopy (FLIR), and Fourier transform spectroscopy. These include photoacoustic infrared spectroscopy, filter-based infrared spectroscopy, differential absorption light detection and ranging, and passive infrared detection

The military uses the M21 Remote Sensing Chemical Agent Alarm (RSCAAL) based on passive infrared detection. It is the first fielded standoff chemical detection device. This system can detect a vapor cloud from 5 km with an 87% detection rate. The M21 RSCAAL continuously monitors a background and notes the change in spectral information if a vapor cloud obstructs the background. It automatically scans along a 60° angle, allowing the operator to monitor horizontal movement. The M21 can be set up in 10 minutes and is unaffected by low light conditions. However, the M21 is limited in that it must be stationary and can be obstructed by snow and rain.

CDE in Civilian response to Terrorist Attacks

CDE technology has advanced primarily as a result of military necessity. More recently, the need for civilian preparedness for terrorist attacks with CA has been recognized. Civilian response is different from military response in many ways, and the choice of CDE must take this into account. Key differences include the following:

- Civilian responders tend to be less experienced in chemical attacks.
- Civilian responders have less information concerning the origin and type of attack and may not recognize that it is a CA attack initially.
- Civilian responders have more stringent budget restraints and thus must use cost-effective equipment.
- Civilian responders have less latitude in incorrectly identifying a CA.
- Civilian responders are deployed primarily to provide medical care, leaving detection as a secondary goal.

In the civilian setting, EMS or other medical providers are the first to arrive. Most EMS providers do not carry CDE to detect CAs and thus initially must recognize the potential threat in order to notify specialized HAZMAT response teams. These teams exist in many cities and are at a minimum equipped with pH paper and combustible gas indicators. This equipment is inadequate in identifying most CAs. Other teams now are equipped with colorimetric tubes Colorimetric tubes are much less expensive than more technical devices, such as the ICAM, and can be distributed generally. Major cities in the US have a Metropolitan Medical Strike Response System (MMRS) organized by the Public Health Service. These are highly specialized, fully equipped, deployable teams to combat civilian threats from weapons of mass destruction. They are primarily medical providers who provide EMS services, decontamination, detection, and treatment. The first such team was organized in 1995 in Washington, DC, and a second was organized for the 1996 Olympics in Atlanta. MMRS teams are often better equipped to respond to CA attacks than HAZMAT response teams. Even so, wide variability exists in the type of detection devices used. A recent study by the National Guard recognized that no standards regulate the detection devices among different civilian emergency response units. MMRS teams can employ any of the devices and technologies described above. They commonly use inexpensive CDE such as SAW detectors and enzymatic techniques such as M9 paper and the M256 kit. Some teams also use IMS devices such as the APD2000 and a modified ICAM for domestic preparedness.

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APPENDIX B

Biological Threat Information

TABLE B-1 Biological Warfare Characteristics

Disease	Transmit Man to Man	Infective Dose (Aerosol)	Incubation Period	Duration of Illness	Lethality (approx. case fatality rates)	Persistence of Organism**	Vaccine Efficacy (aerosol exposure)
Inhalation anthrax	No	8,000-50,000 spores	1-6 days	3-5 days (usually fatal if untreated)	High	Very stable - spores remain viable for > 40 years in soil	2 dose efficacy against up to 1,000 LD_{50} in monkeys
Brucellosis	No	10-100 organisms	5-60 days (usually 1-2 months)	Weeks to months	<5% untreated	Very stable	No vaccine
Cholera	Rare	10-500 organisms	4 hours - 5 days (usually 2-3 days)	≥ 1 week	Low with treatment, high without	Unstable in aerosols & fresh water; stable in salt water	No data on aerosol
Glanders	Low	Assumed low	10-14 days via aerosol	Death in 7-10 days in septicemic form	> 50%	Very stable	No vaccine
Pneumonic Plague	High	100-500 organisms	2-3 days	1-6 days (usually fatal)	High unless treated within 12-24 hours	For up to 1 year in soil; 270 days in live tissue	3 doses not protective against 118 LD_{50} in monkeys
Tularemia	No	10-50 organisms	2-10 days (average 3-5)	≥ 2 weeks	Moderate if untreated	For months in moist soil or other media	80% protection against 1-10 LD_{50}
Q Fever	Rare	1-10 organisms	10-40 days	2-14 days	Very low	For months on wood and sand	94% protection against 3,500 LD_{50} in guinea pigs
Smallpox	High	Assumed low (10-100 organisms)	7-17 days (average 12)	4 weeks	High to moderate	Very stable	Vaccine protects against large doses in primates
Venezuelan Equine Encephalitis	Low	10-100 organisms	2-6 days	Days to weeks	Low	Relatively unstable	TC 83 protects against 30-500 LD_{50} in hamsters
Viral Hemorrhagic Fevers	Moderate	1-10 organisms	4-21 days	Death between 7-16 days	High for Zaire strain, moderate with Sudan	Relatively unstable - depends on agent	No vaccine
Botulism	No	0.001 μg/kg is LD_{50} for type A	1-5 days	Death in 24-72 hours; lasts months if not lethal	High without respiratory support	For weeks in nonmoving water and food	3 dose efficacy 100% against 25-250 LD_{50} in primates
Staph Enterotoxin B	No	0.03 μg/person incapacitation	3-12 hours after inhalation	Hours	< 1%	Resistant to freezing	No vaccine
Ricin	No	3-5 μg/kg is LD_{50} in mice	18-24 hours	Days - death within 10-12 days for ingestion	High	Stable	No vaccine
T-2 Mycotoxins	No	Moderate	2-4 hours	Days to months	Moderate	For years at room temperature	No vaccine

Note: Table source is the Medical Management of Biological Casualties Handbook, from the United States Army Research Institute for Infectious Diseases.
**Persistence varies on surfaces, in soil and water, and in open air depending upon many factors including temperature, humidity, exposure to sunlight, etc.
Caution should be used to prevent overstatement of the limited persistence data in this table.

TABLE B-2 Biological Warfare Agents – Vaccine, Therapeutics, and Prophylaxis

DISEASE	VACCINE	CHEMOTHERAPY (Rx)	CHEMOPROPHYLAXIS (Px)	COMMENTS
Anthrax	Bioport vaccine (licensed) 0.5 mL SC @ 0, 2, 4 wk, 6, 12, 18 mo then annual boosters	Ciprofloxacin 400 mg IV q 12 h, or Doxycycline 200 mg IV, then 100 mg IV q 12 h	Ciprofloxacin 500 mg PO bid x 4 wk If unvaccinated, begin initial doses of vaccine	Potential alternates for Rx: gentamicin, erythromycin, and chloramphenicol
		Penicillin 4 million units IV q 4 h	Doxycycline 100 mg PO bid x 4 wk plus vaccination	PCN for sensitive organisms only
Cholera	Wyeth-Ayerst Vaccine 2 doses 0.5 mL IM or SC @ 0, 7-30 days, boosters Q 6 months	Oral rehydration therapy during period of high fluid loss	NA	Vaccine not recommended for routine protection in endemic areas (50% efficacy, short term)
		Tetracycline 500 mg q 6 h x 3 d Doxycycline 300 mg once, or 100 mg q 12 h x 3 d		Alternates for Rx: erythromycin, trimethoprim and sulfamethoxazole, and furazolidone
		Ciprofloxacin 500 mg q 12 h x 3 d		Quinolones fortetra/doxy resistant strains
		Norfloxacin 400 mg q 12 h x 3 d		
Q Fever	IND 610 - inactivated whole cell vaccine given as single 0.5 ml s.c. injection	Tetracycline 500 mg PO q 6 h x 5-7 d continued at least 2 d after afebrile	Tetracycline 500 mg PO qid x 5 d (start 8-12 d post-exposure)	Currently testing vaccine to determine the necessity of skin testing prior to use.
		Doxycycline 100 mg PO q 12 h x 5-7 d continued at least 2 d after afebrile	Doxycycline 100 mg PO bid x 5 d (start 8-12 d post-exposure)	
Glanders	No vaccine available	Antibiotic regimens vary depending on localization and severity of disease	Post-exposure prophylaxis may be tried with TMP-SMX	No large therapeutichuman trials have been conducted due to the rarity of naturally occurring disease.
Plague	Greer inactivated vaccine (FDA licensed) is no longer available.	Streptomycin 30 mg/kg/d IM in 2 divided doses x 10–14 d or Gentamicin 5 mg/kg or IV once daily x 10-14 d, or Ciprofloxacin 400 mg IV q 12 h until clinically improved then 750 mg PO bid for 10–14 d	Doxycycline 100 mg PO bid x 7 d or duration of exposure Ciprofloxacin 500 mg PO bid x 7 d	Chloramphenicol for plague meningitis is required 25 mg/kg IV, then 15 mg/kg qid x 14 d
		Doxycycline 200 mg IV then 100 mg IV bid, until clinically improved then 100 mg PO bid for total of 10-14 d	Tetracycline 500 mg PO qid x 7 d	Alternate Rx: trimethoprim-sulfamethoxazole
Brucel-losis	No human vaccine available	Doxycycline 200 mg/d PO plus rifampin 600 mg/d PO x 6 wk	Doxycycline 200 mg/d PO plus rifampin 600 mg/d PO x 6 wk	Trimethoprim-sulfamethoxazole may be substituted for rifampin; however, relapse may reach 30%
		Ofloxacin 400/rifampin 600 mg/d PO x 6 wks		

(continued)

TABLE B-2 (continued)

DISEASE	VACCINE	CHEMOTHERAPY (Rx)	CHEMOPROPHYLAXIS (Px)	COMMENTS
Tularemia	IND - Live attenuated vaccine: single 0.1 ml dose by scarification	Streptomycin 7.5-10 mg/kg IM bid x 10-14 d	Doxycycline100 mg PO bid x 14 d	
		Gentamicin 3-5 mg/kg/d IV x 10-14 d	Tetracycline 500 mg PO qid x 14 d	
		Ciprofloxacin 400 mg IV q 12h until improve, then 500 mg PO q 12hx10-14 d	Ciprofloxacin 500 mg PO q 12h for 14 d	
		Ciprofloxacin 750 mg PO q 12h, 10-14 d		
Viral encephalitides	VEE DOD TC-83 live attenuated vaccine (IND): 0.5 mL SCx1 dose	Supportive therapy: analgesics and anticonvulsants prn	NA	TC-83 reactogenic in 20%, No seroconversion in 20%, Only effective against sub types 1A, 1B, and 1C
	VEE DOD C-84 (formalin inactivated TC-83) (IND): 0.5 mL SC for up to 3 doses			C-84 vaccine used for non-responders to TC-83
	EEE inactivated (IND): 0.5 mL SC at 0 & 28 d			EEE and WEE inactivated vaccines are poorly
	WEE inactivated (IND): 0.5 mL SC at 0, 7, and 28 d			Immunogenic. Multiple immunizations are required
Viral Hemorrhagic Fevers	AHF Candid #1 vaccine (x-protection for BHF) (IND)	Ribavirin (CCHF/Lassa) (IND) 30 mg/kg IV initial dose; then 16 mg/kg IV q 6h x 4 d; then 8 mg/kg IV q 8hx 6 d	NA	Aggressive supportive care and management of hypotension very important
	RVF inactivated vaccine (IND)	Passive antibody for AHF, BHF, Lassa fever, and CCHF		
Smallpox	Wyeth calf lymph vaccinia vaccine (licensed): 1 dose by scarification	No current Rx other than supportive; Cidofovir (effective in vitro); animal studies ongoing	Vaccinia immune globulin 0.6 mL/kg IM (within 3d of exposure, best within 24 h)	Pre and post exposure vaccination recommended if > 3 years since last vaccine
Botulism	DOD pentavalent toxoid for serotypes A-E (IND): 0.5 ml deep SC @ 0, 2 & 12 wk, then yearly boosters	DOD heptaval entequine despeciated antitoxin for serotypes A-G (IND): 1 vial (10 mL) IV	NA	Skin test for hypersensitivity before equine antitoxin administration
		CDC trivalent equine antitoxin for serotypes A, B, E (licensed)	NA	
Staphylococcus Enterotoxin B	No vaccine available	Ventilatory support for inhalation exposure	NA	
Ricin	No vaccine available	Inhalation: supportive therapy G-I : gastric lavage,super activated charcoal, cathartics	NA	
T-2 Mycotoxins	No vaccine available		Decontamination of clothing and skin	

APPENDIX C

Radiological Threat Information

C.1 HUMAN HEALTH EFFECTS AND PROTECTION FROM RADIATION

Since the discovery and use of radium and radiation around the beginning of the 20th century, many medical studies have been performed to determine the human health effects of radiation doses. Radiation exposure is classified as either acute or chronic where acute is a short time frame exposure on the order of seconds to hours whereas chronic exposure is long-term exposure over a period of years. A large acute or chronic dose to the whole body can cause serious health effects including death whereas smaller chronic doses can cause cancer over periods of 10 to 50 years. Acute whole body radiation dose human health effects are summarized in Table C-1. The health effects of chronic radiation dose over a 50-year time period, which increase the risk of lifetime latent cancer fatality is presented in Table C-2. It should be noted that radiation doses to just one specific part or organ of the body may have different and, sometimes, less life-threatening consequences.

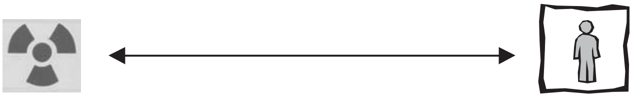
This table shows that insignificant health effects would be expected for acute doses up to 10 rem and a small percentage of the general population would experience some discomforting temporary symptoms for doses of 10 to 100 rem. Acute doses over 100 rem require medical intervention and become life threatening with more serious symptoms.

Protection from radioactive material involves different strategies for different types of radioactive hazards. External gamma, X-ray, and neutron radiation hazards must be managed by using the three basic rules of radiation protection: time, distance, and shielding, which are explained below.

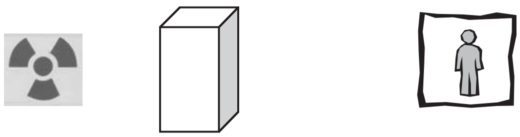
EXTERNAL RADIATION HAZARD PROTECTION RULES

MINIMIZE RADIATION EXPOSURE TIME

MAXIMIZE DISTANCE FROM RADIATION SOURCES



MAXIMIZE APPROPRIATE RADIATION SHIELDING



In a radiation field of "X" mrem/hour, the total dose one receives is the time of exposure multiplied by the dose rate. Therefore, the shorter the exposure time, the smaller the dose. Since radiation emanates in all directions from radioactive materials, the dose rate from a radiation source decreases as distance from it increases. Placing the right kind of shielding between you and the radiation source will reduce the dose rate and dose since the shielding absorbs or attenuates the radiation before it reaches you. The best shielding for gamma and X-ray radiation is heavy, high-density material (iron, steel, lead, high-density concrete) while neutrons are best shielded by materials which contain hydrogen or other light elements in a high density such as concrete, special plastic formulations, or water. The simplest of these three rules to follow in an emergency first response situation is to minimize time and maximize distance.

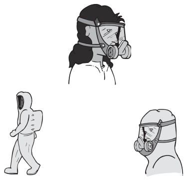
Protection from internal radiation hazards such as the inhalation or ingestion of alpha or beta radiation emitting radioisotopes requires a different approach presented below.

INTERNAL RADIATION HAZARD PROTECTION RULES

WEAR RESPIRATORY PROTECTION

WEAR ANTI-CONTAMINATION SUIT

{WITH RESPIRATORY PROTECTION}



These hazards are managed or mitigated by the use of respirators or professional air filtration masks along with anti-contamination (Anti-C) suits, which are plastic or other easily washed surface material full body suits that, along with boots and hoods, cover the entire body and prevent any deposition or inhalation of radioactive particles. High efficiency air filtration masks or independent air supply masks may already be part of many first responders equipment (i.e., firefighters) or can easily be added to their inventory. Anti-C suits are more complex, expensive, time consuming, and larger pieces of equipment for the transportation system first responder. Although important, the Anti-C suits should take a second priority to air filtration or independent air breathing masks. This is because the masks will preclude the introduction of radioactive particles inside the human body whereas the suits prevent the deposition of radioactive particles on the skin and hair of humans. It is much easier to decontaminate skin/hair of radioactive particles than to remove inhaled or ingested radioactive material.

TABLE C-1 Acute Radiation Dose Human Health Effects

Acute Dose to Whole Body (rem)	Expected Human Health Effects
<1 rem	No health effects
1 to 10 rem	No discernible health effects except for possible dry mouth, headaches and anxiety; insignificant increase in lifetime cancer risk, full recovery
10-100	Slight (<5%) incidence of nausea, vomiting, headache; temporary drop in white blood cell count; 0.5%-5% increase in lifetime cancer risk; full recovery
100-300	5-50% of population experience nausea and vomiting, long term drop in white blood cell count, fatigue, weakness, infection susceptibility, loss of appetite, skin reddening, hair loss, 5-15% increase in lifetime cancer fatality, some cataract formation, 5-10% population fatality within 30-60 days; significant medical care required for full recovery
300-500	50-100% of population experience nausea and vomiting, 10-50% population fatality within 30-60 days; hemorrhaging, extensive medical care may prevent mortality
500-800	Permanent sterilization, cataracts in 100% of population, 50-90% population fatality within 30-60 days; extreme medical care may prevent mortality
800-3000	Skin blistering, 90-100% population fatality in 2 to 3 weeks; little chance of survival with even most extreme and intensive medical care

TABLE C-2 50-Year Chronic Radiation Dose Human Health Effects

Total 50-Year Chronic Whole Body Radiation Dose (rem)	Expected Public Human Health Effects (Lifetime Probability of Latent Fatal Cancer)
15 (natural background)	0.8%
50 [1 rem/year]	2.5%
100 [2 rem/year]	5%
1000 [20 rem/year]	50%

C.2 NEAR TERM MEDICAL TREATMENT FOR EXTERNAL RADIATION AND INTERNAL RADIOACTIVE CONTAMINATION

Members of the public in proximity to a radiological threat can be treated so as to significantly reduce their individual radiation dose. Rapid movement away from the location of radioactive material will reduce doses based on the previously discussed basic rules of thumb regarding minimizing time and maximizing distance. Relocation to a controlled area and subsequent removal of all clothing and washing down all body surfaces will reduce contamination doses and mitigate inhalation or ingestion of radioactive particles. Since radiation doses can compromise the immune system, prompt treatment of all cuts and burns and the administration of appropriate topical, oral, and injected antibiotics will prevent possibly serious infections.

A number of drugs and chemicals have been recognized by medical authorities as being effective in the treatment of specific radioisotope internal contamination by inhalation, ingestion, or absorption through open wounds. These drugs either saturate an organ of the body to prevent it from absorbing the radioisotope or they rapidly increase the body’s excretion of the radioisotope. One drug can reduce the chance of latent cancer due to radiation exposure only if administered before exposure and would therefore be useful for first responders only. These are summarized in Table C-3.

Although no drugs should be administered to members of the public exposed to a radiological incident until the specific radioisotope(s) involved have been identified, maintaining a stockpile of treatment drugs, which can be quickly accessed, could significantly reduce treatment time and the resulting radiation dose to the public.

It should be noted that members of the public removed from the area around an RDD or ATS should be isolated from the general public and uncontaminated areas. Even after skin and hair decontamination by intense washing and removal of all clothing, humans may be secreting radioisotopes in their liquid and solid wastes, which should also be controlled and isolated from the sewage system.

C.3 FEDERAL PUBLIC RADIATION STANDARDS, REGULATIONS, AND GUIDANCE

Federal government agencies involved with handling, use, and regulation of radioactive material have developed standards, limits, and criteria for allowable public exposure to radiation. Separate, and more relaxed, standards exist for workers in the nuclear industry. However, transportation system responders to a radiological threat are not considered nuclear workers, but should be treated as the public in terms of radiation dose limits. These radiation dose limits were all derived based on normal activities and operations or accidents at

TABLE C-3 Approved Drugs or Chemicals for Radiation Treatment

Inhaled or Ingested Radioisotope or External Radiation	Drug or Chemical	Treatment Form and Treatment Conditions
Iodine-125	Potassium Iodide, Potassium Iodate, or Sodium Iodide[1]	Pills As soon as possible after exposure and daily for two weeks
Cesium-137	Ferric Hexacyanoferrate (II) aka Prussian Blue	Solution or pill Three times daily for three weeks
Plutonium-238 Americium-241 Curium-244 Californium-252	Calcium or Zinc diethylenetriaminepentaacetate (Ca-DTPA[2] or Zn-DTPA) or EDTA	Solution intravenous or as an inhaler As soon as possible Daily for up to 5 days
Strontium-90	Aluminum phosphate or barium sulfate	Oral, as soon as possible
Any Uranium isotope	Sodium Bicarbonate	IV or pills every four hours to protect kidneys
Tritium (Hydrogen-3)	Water	Orally and/or IV forced fluids
Gamma and neutron radiation exposure	Amifostine (phosphorylated aminothiol)	Intravenous at least one hour before exposure
High radiation dose to bone marrow	Cytokines	Pills or injection (up to 11 days)

[1] suitable alternative for individuals with potassium allergic reaction
[2] preferred over Zn-DTPA and EDTA

nuclear facilities, but not in the context of homeland security or radiological threats to transportation systems. Table C-4 presents public radiation dose limits set forth and treated as law by different federal government agencies.

The federal public radiation dose limits in Table A.4 are a small fraction of natural radiation for normal operations of facilities that contain radioactive materials. The only exception is that of a nuclear power plant accident, which allows significant, but non-fatal, public doses. It is also interesting to note that transportation packages containing radioactive material can have a significant dose rate, by DOT regulation. However, even if one were to be in contact with the maximum allowed 200 mrem/hour package, it would take 500 hours (21 days) of continuous contact to receive a 100 rem dose where there is a small probability of death. It is important to note that none of the dose limits in Table 8.6 were designed or intended for an RDD or ATS scenario. The EPA, in 1992, promulgated radiological protection guidance for state and local officials in the case of a non-nuclear weapon nuclear incident. This guidance is in the form of Protective Action Guides (PAGs), which are public doses at which specific actions should be taken during an incident or emergency. These EPA PAGs are presented in Table C-5.

For this study, only the EPA early incident phase is of interest. Therefore, first responders should be able to measure any radiation dose rate such that continued public exposure in the area would result in a dose rate of 1 rem or greater. This is equivalent to a dose rate as low as about 1 mrem/hr. for a 4-day contiguous public presence and as high as 1 rem/hr. for a one-hour contiguous public presence. This requirement is met by the previously discussed radiation detection survey meter specifications of 0.1or 1 mrem/hr. to 100 or 1000 rem/hr. The PAG for early response to doses greater than 25 rem assumes that this high dose is due to the inhalation and/or ingestion of radioactive iodine, which naturally concentrates in the body's thyroid and can cause thyroid cancer at high doses. Under medical supervision, the administration of non-radioactive iodine pills, usually in the form of potassium iodide will saturate the thyroid with non-radioactive iodine and mitigate any absorption of the radioactive iodine. This action will only be effective if radioactive iodine is involved. The first responder's radiation detection instrument will not determine specific radioisotopes, only the magnitude of the radiation dose rate field.

C.4 RADIOLOGICAL DISPERSAL DEVICE RADIOISOTOPE PROPERTIES

Radioactive material, in the form of radioisotopes, are produced and used worldwide for industrial, research and medical applications. The control and accounting of devices, which contain radioisotopes, has not been subject to the same level as nuclear weapons and nuclear fuel. Worldwide, thousands of radioisotope devices have been unaccounted for and provide an ideal source for radioactive material threats to transportation. Several studies have been performed to determine the most likely radioisotopes that could be used in a radiological dispersal device (RDD). These radioisotopes were selected based on their availability, half-life, radiological hazard, and radiation energy. A list of the most likely RDD radioisotopes was synthesized from several sources and presented in Table C-6 along with some key radiation properties.

TABLE C-4 Federal Government Agency Public Radiation Dose Limits

U.S. Federal Agency	Type of Public Radiation Dose	Public Limit or Criteria (millirem)	Federal Regulation Citation
Nuclear Regulatory Commission (NRC)	Whole body from normal operations of NRC-licensed facilities; Special exemption for individual members of public	100 per year 500 per year	10 CFR 20.1301 10 CFR 20.1301
NRC	External dose rate in unrestricted area at NRC-licensed facility	2 per hour	10 CFR 20.1301
NRC	Whole body from cleanup and shutdown of NRC-licensed facility	25 per year (/yr.)	10 CFR 20.1403
NRC	Accident at nuclear power plant -whole body - thyroid	25,000/yr. 300,000/yr.	10 CFR 100.11
NRC	Local skin surface dose	50,000/yr.	10 CFR 20
NRC	Due to low level radioactive waste disposal repository -whole body -thyroid -other organs	25/yr. 75/yr. 25/yr.	10 CFR 61.41
Environmental Protection Agency (EPA)	Breathing air	10/yr.	
EPA	Drinking water	4/yr.	40 CFR 141.66
EPA	Normal nuclear power plant operation -whole body -thyroid -other organs	25/yr. 75/yr. 25/yr.	40 CFR 190.10
EPA	Spent nuclear fuel and radioactive waste storage -whole body -thyroid other organs	25/yr. 75/yr. 25/yr.	40 CFR 191.03
EPA	Underground Uranium Mines	10/yr.	40CFR61(Sub B)
EPA	Department of Energy (DOE) Facilities	10/yr.	40CFR61 (Sub H)
EPA	National nuclear waste repository at Yucca Mountain, Nevada	15/yr.	40 CFR 197
Department of Transportation (DOT)	Dose rate at outer surface of vehicle package containing radioactive material	200 per hour	49 CFR 173.441
DOT	Dose rate at 6.6 feet from the outer surface of transport vehicle containing radioactive material	10 per hour	49 CFR 173.441

TABLE C-5 EPA Protective Action Guides (PAGs) for a Radiological Incident

Incident Phase	Public Dose (rem)	Action
Early (first 4 days)	1.0 to 5.0 (whole body)	Evacuation or Sheltering
Early	25.0 (thyroid)	Administer Stable Iodine
Intermediate (4 days to one year)	≥ 2.0 (whole body)	Relocation
Intermediate	< 2.0 (whole body)	Apply Dose Reduction techniques

As previously discussed, radiation from an RDD can only be detected by specifically designed measurement instruments. There is a wide spectrum of radiation detectors available, each of which is designed for a specific function. For the purposes of transportation system emergency response, a general-purpose survey meter would be the most appropriate instrument. Each radiation-measuring instrument consists of three basic components: the detector, electronic signal processor, and display-controls. The detector, which could be integral to the instrument or connected by wire to be hand held separately, produces an electric signal when radiation enters it. No one single detector can measure alpha, beta, gamma, and neutron radiation. The electronic signal processor converts the signal into an electric driver for the display panel. The display-controls allow the user to operate the instrument and visually (also sometimes aurally) be

TABLE C-6 Most Likely RDD Radioisotopes and their Radiation Properties

Radioisotope [physical form] {body organ in which it accumulates}	Half-Life [Curies per gram][1]	Type of Radiation Emitted	Maximum Energy of Radiation Emitted (Mev)
Cobalt-60 [solid metal] {liver and body tissues}	5.3 years [1,130]	Beta, gamma	0.3, ***1.3***
Iodine-125 [chemically reactive, soluble, low melting and boiling point crystalline solid] {thyroid}	60 days [17,400]	Beta, gamma	0.15, 0.04
Cesium-137 [solid soluble salt] {muscles}	30.1 years [87]	Beta, gamma	0.5, 0.7
Iridium-192 [solid silvery white metal]	84 days [9,170]	Beta, gamma	0.8, 0.5
Strontium-90 [solid silvery metal] {bones and teeth}	29.1 years [141]	Beta	0.5
Plutonium-238 [solid heavy metal] [liver and skeleton}	88 years [17]	Alpha, beta, gamma	5.5, 0.01, 0.002
Radium-226 [solid heavy metal] {bone and teeth}	1,600 years [0.988]	Alpha, beta, gamma	4.8, 3.0, ***2.0***
Americium-241 [solid heavy metal] {liver and skeleton}	433 years [3.5]	Alpha, beta, gamma	5.5, 0.05, 0.06
Curium-244 [solid heavy metal] {liver and skeleton}	18 years [80.9]	Alpha, beta, gamma, neutrons	5.8, 0.09, 0.002, ***2.5***
Californium-252 [solid heavy metal] {liver and skeleton}	2.6 years [546]	Alpha, beta, gamma, neutron	6.0, 0.04, 0.9, ***2.0***

[1] = Indicates how much mass is needed for a given amount of radioactivity, for example one gram of Cobalt-60 has over 1,000 times the radioactivity of one gram of radium-226.

[____] = highest radioactivity per unit of mass

bold **=** highest energy gamma or neutron emitter; greatest external radiation hazard

informed of the magnitude of the radiation dose rate at the detector.

A general-purpose survey radiation detection meter, which can detect alpha, beta, and gamma radiation (all the radioisotopes listed in Table A.3 emit alpha, beta, or gamma radiation) over a wide range of dose rates, is rugged, portable, and easy to use is the optimum instrument for first responders to a transportation system threat, which may involve a RDD. This meter is not required to measure dose rates to a high degree of accuracy (± 20–50% is acceptable) and will not identify the individual radioisotope(s), which are the source of radiation. These capabilities require more complex, expensive, cumbersome, and heavier instrumentation. Subsequent emergency responders from appropriate nuclear agencies will have this capability. The initial emergency responders only need to identify if radioactive material was released, the general magnitude of the radiation dose field, and the physical locations of deposited radioactive contamination.

Analysis of the most likely RDD radioisotopes and their relevant properties, which are delineated in Table C-3, points to a "pancake-type" Geiger-Muller tube or an ionization chamber detector as the optimum meter to detect each of these radioisotopes. Good quality radiation detectors using either the ionization chamber or Geiger-Muller tube are estimated to cost between $400 and $1500 each. A number of manufacturers can offer such detectors including: Ludlums, Canberra, BNFL, Laurus, Atlantic Nuclear, Cardinal Health (used to be Victoreen), and Thermo-Eberline.

C.5 EXAMPLES OF ANALYZED RDD INCIDENT EFFECTS

Figures C-1 and C-2 illustrate typical dispersion maps showing how the radioisotope concentration, contamination (and radiation dose rate) changes from the point of release out to different distances for an incident in Washington, D.C. and New York City. Figure A-1 shows the plume of radioactive contamination from an RDD incident at the National Gallery of Art with a wind towards the southeast. Figure C-2 shows radioactive contamination plume from an RDD in downtown Manhattan with a wind blowing towards the northeast. The boundary of each constant shade area represents a contour of constant radiation dose rate. Within the shaded area, the dose

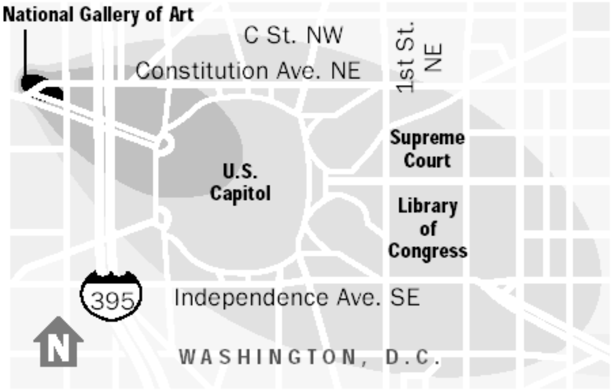


Figure C-1. Washington D.C. hypothetical RDD radiation dose rate and contamination.

rate and level of radioactive contamination is a value between the two contour boundary lines.

In each scenario, the direction of the oval or parabolic distribution of radioactive material is following the wind direction and each release includes the energy of a small quantity of TNT with the radioisotope. The rate of dilution and spreading of a plume is controlled by the intensity of turbulence in the atmosphere. Turbulence increases with wind speed, traffic, and heat emitted from buildings. The turbulence has two different effects on spreading radioactivity. The higher turbulence spreads the contamination over a greater area, but also dilutes the contamination with more air as compared to a lower turbulence. The time for radioactive material to reach a specific distance is directly related to wind speed.

Figure C-2. New York City hypothetical RDD radiation dose rate and contamination

Both Figures C-1 and C-2 are examples of dispersion of fine solid particulate radioactive material in an outside and relatively open location. Release in an enclosed space such as a tunnel, subway station, aircraft, or other transportation vehicle would be subject to an entirely different behavior. Radioactive particulate distribution would be more concentrated within the enclosed space or volume. In a tunnel or underground station, airflow and the movement of vehicles and humans would spread contamination. While moving, airflow out of any transportation vehicle (e.g., truck, train car, subway car, aircraft, etc.) would carry a stream of radioactive particles to the surrounding environment.

C.6 HISTORICAL RADIOLOGICAL INCIDENTS INVOLVING TRANSPORTATION SYSTEMS

In the approximately 100 years since the discovery and use of radioactivity, numerous radiological incidents have occurred that resulted in unintended radiation doses to individuals and radioactive contamination. During the first 60 years of the twentieth century, most incidents were due to a lack of knowledge of the biological limits of radiation or were associated with the research and development of nuclear technology for military applications. The most commonly known nuclear incidents in the area of civilian nuclear applications are the Chernobyl and Three Mile Island nuclear power plant accidents in 1986 and 1979, respectively. These events did not directly involve a transportation system and emergency response was led and controlled by federal government agencies.

In the U.S., about three million shipments of radioactive materials by highway, rail, air, and sea are made annually. No deaths or serious injuries have ever been attributed to radiation from these shipments. Since 1971, 45 million packages of radioactive material have been shipped and 3,453 have been involved in accidents, but only 197 of these resulted in enough damage to release any radioactivity. No radiation doses to the public or workers were serious enough to require medical care or violated government limits. Evaluation of historical data on radiological incidents was focused specifically on transportation related events with representative events presented in Table C-7.

This table shows that very little radioactive material release or contamination has ever been released from civilian transportation. Most civilian radioactive accidents have had no public or worker health effects.

TABLE C-7 Historical Representative Transportation System Radiological Release Incidents

Date	Transport Mode	Incident Description
1954	Sea	Experimental navy nuclear submarine Seawolf was scuttled in 9,000 feet of water off the Delaware/Maryland coast with 33,000 Curies of radioactivity released; never recovered
1958	Highway	Tank trailer with 1,500 gallons of liquid uranium solution overturned near Hanford, Washington when brakes failed on hill. Contaminated fluid was flushed into ditch and soil was shipped to a radioactive waste storage site. (Washington state)
1960	Truck	Spent nuclear fuel cask leak onto trailer floor, contamination confined to vehicle
1963	Rail	Spent nuclear fuel cask leak, contamination confined to cask and trailer
1964	Air (Space)	U.S. nuclear powered navigation satellite burns in the atmosphere releasing 17,000 Curies of Plutonium-238
1966	Air	B-52 bomber crashes with air tanker over Spain, two H-bombs fall near Palomares, their conventional explosive component detonates and spreads radioactive contamination. About ten pounds (about 278 Curies) of plutonium-239 spread over 650 acres. Over three months, 1,500 tons of topsoil and plants shipped to U.S. burial site. 800 U.S. military personnel and 900 Spanish civil guards used in cleanup. Total cleanup cost, not including lost aircraft, was $ 100 million
1971	Sea	500 gallons of radioactive water spilled in Thames River near New London, Connecticut while being transferred from nuclear submarine Dace to sub tender Fulton (Connecticut)
1971	Highway	Tractor-trailer with 25-ton cask containing spent nuclear fuel overturned after swerving to avoid head-on collision. The trailer broke away and skidded into water filled ditch. No radioactive material was released.
1978	Air (Space)	Russian Cosmos 954 nuclear powered satellite crashes into Canada's desolate unpopulated Northwest Territories spreading spent nuclear fuel radioactive contamination over 15,000 square miles. Fragment radiation dose from mrem/hr. to 100 rem/hr. Cleanup took three months and about $7Million (Canada)
1978	Sea	500 gallons of radioactive water released to Puget Sound, Washington when nuclear submarine Puffer accidentally opened valve (Washington state)
1987	Sea	French Cargo Ship Mont Louis with 350 tons of uranium hexafluoride sunk in a collision with a car ferry 9 miles from the coast of Belgium in 49 feet of water. The 30 casks were recovered and only one was found to be leaking.
1997	Sea	MSC Carla split in two in a storm. It carried 3 casks holding a total of 9 Curies of Cesium-137 as Cesium Chloride. It sunk in 9800 feet of water in North Atlantic North of Azores and no recovery was attempted.
1997	Rail	Special train car with containers of Iridium-192 and Cobalt-60 collided with bulldozer, containers were broken and spread radioactive contamination (Russia)
1999	Highway	Accident between 2 Trucks, both caught fire, one truck was carrying containers and syringes with radioactive material. All radioactive material was contained and accounted for with no highway contamination (Ohio)
2000	Air	A package containing two 0.05 mCi Californium-252 sources was damaged by a fork lift truck during cargo handling at an airport terminal. Confinement was not breached. (U.K.)
2003	Rail	Rail car carrying radioactive waste struck another rail car in the rail yard loosening cover of car, but no radioactive material was released (Maine)

APPENDIX D

TERET Tool Users Manual

Preliminary Draft Final Report

NCHRP Project 20-59(19), FY 2004

TRANSPORTATION RESPONSE OPTIONS: SCENARIOS OF INFECTIOUS DISEASES, BIOLOGICAL AGENTS, RADIOLOGICAL, CHEMICAL AND OTHER HAZARDOUS MATERIALS: A GUIDE TO TRANSPORTATION'S ROLE IN PUBLIC HEALTH DISASTERS

Task 9: User Manual for the Transportation Emergency Response Effects Tracking (TERET) Tool

Prepared for:

National Cooperative Highway Research Program
Transportation Research Board
National Research Council

TRANSPORTATION RESEARCH BOARD, NAS-NRC PRIVILEGED DOCUMENT

This report, not released for publication, is furnished only for review to members of or participants in the work of the National Cooperative Highway Research Program (NCHRP). It is to be regarded as fully privileged, and dissemination of the information included herein must be approved by the NCHRP.

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September 2005

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Preface

TERET is one of three products developed under the National Cooperative Highway Research Program (NCHRP 20-59 (19)) of the Transportation Research Board. The project's overall objective is to develop a guide to assist state and local transportation managers in the development of transportation response options to extreme events involving chemical, biological, or radiological (CBR) agents. The project is applicable to all civilian sites (not just transportation sites) and focuses on the impact and role of transportation during such an event. TERET is intended to be used as a guide during emergency response planning stages, as well as during an emergency response exercise or actual event. The primary users are expected to be transportation planners and managers at emergency management centers.

The other products of the project are: (1) A report titled: Transportation Response Options: Scenarios of Infectious Diseases, Biological Agents, Radiological, Chemical and Other Hazardous Materials: A Guide To Transportation's Role in Public Health Disasters.This report contains technical information on chemical, biological, and radiological threats including vulnerabilities of the transportation system to these agents and consequence minimization actions that may be taken within the transportation system in response to these events.The report also includes a summary of the US transportation system and an overview of mode-specific emergency response plans. (2) A slide presentation titled: An Introduction to Biological, Chemical, and Radiological Threat Agents. This MS PowerPoint presentation includes presenter notes, and is designed as an executive communications tool based on summary information from the previously listed report.

1.0 Introduction

Transportation Emergency Response Effects Tracking (TERET) is designed to assist transportation and emergency managers in projecting potentially critical conditions that may develop as a result of changes in transportation services due to a large emergency event. During both response and recovery from an emergency event, traffic patterns are altered by emergency response actions that cause traffic detours and lane re-directions, restricted access, reduced or suspended service, equipment and personnel re-allocations, etc. These changes or disruptions in traffic patterns may have critical effects on deliveries and worker transport for essential services that must be continuously maintained despite emergency events. Altered traffic patterns may also influence, and be influenced by the use of the transportation system for mass care needs associated with an emergency event.

1.1 Overview of TERET

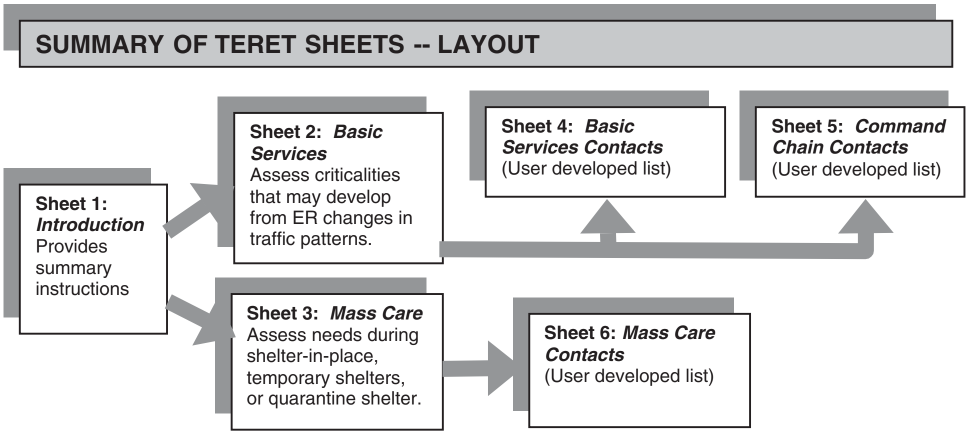
TERET is a *Microsoft Excel* ™ workbook designed to help managers and planners assess the effects of emergency response actions on transportation at state and local levels. TERET has two separate components. These components and their objectives are:

- **Essential Services Transportation** – This refers to the use of the transportation system for providing essential services for community health and sustenance. TERET's objective is to assist in identification of criticalities that may arise in essential services as a result of traffic pattern changes and associated delays in deliveries and services, and to facilitate the identification of solutions to prevent or mitigate these criticalities.
- **Mass Care Transportation** – This refers to transportation system use for the transport of people to decontamination, triage, and medical service/hospital sites, and the provision of supplies needed for populations in shelter-in-place; temporary shelter; and quarantine shelter. TERET's objective is to provide a list of some of the types of transportation that may be needed for these actions, and to calculate the remaining time these transportation services will be needed based on command chain estimates of the overall duration of these needs.

TERET has four basic worksheets: (**Figure 1**)

- **Worksheet 1** -- provides summary instructions for the use of TERET.
- **Worksheet 2** -- contains a template for assessment of criticalities that may arise in essential services as a result emergency response effects on traffic patterns. This worksheet may be copied for use in new scenarios.
- **Worksheet 3** -- contains a template for assessment of mass care transportation needs. This worksheet may be copied for use in new scenarios.
- **Worksheet 4** -- contains a template for user-developed lists of contacts that can provide data for Worksheets 1 and 2.

Figure 1. Schematic Layout of the TERET Worksheets



Worksheets found after Worksheet 4 contain copies of Worksheet 2, filled in with hypothetical data to represent scenarios described in Section 4 of this manual. These should be used only for instructional purposes.

1.2 Customizing and Using TERET

Prior to use of TERET during an event or exercise, users must collect and enter area-specific data. Time required for collecting this information will vary substantially among users, but in general, expect initial data collection to take in the range of 6 to 16 hours spread over a week or more. (Subsequent updates should be much quicker.) New users should begin their data entry on the blank templates in Worksheets 2 and 3. The scenario worksheets contain copies of these templates with hypothetical data that should not be used as default or surrogate values.

Side-bars, such as the example to the right, draw attention to sections that discuss data needed as pre-event information. Pre-event data that users must enter is briefly listed in **Table 1**, and explained in greater detail in the following sections.

! Pre-Event Information

These are alerts for information you must add before applying TERET.

Table 1. Type of Pre-Event Information Collection Needed, by Worksheet

Worksheet	Data Needed Prior to TERET Use
2 – Essential Services	Modes used; time to criticality; severity level; potential solutions; command chain contact for a pending criticality.
3 – Mass Care	Command chain contact for estimation total hours of site activation; lead time between mass care site activation and supply need.
4 – Contacts	Contact information for data needed in “Essential Services” and “Mass Care” worksheets.

1.3 User Proficiency with MS Excel

Use of TERET requires a basic level of proficiency with MS Excel. In addition to basic data entry, file saving, and cutting and pasting, the user should be able to add new rows and columns, and should be familiar with the use and creation of comment boxes. For users not familiar with these Excel features, some explanatory notes are provided in the boxes below.

MS Excel Notes

Adding and Deleting Rows and Columns

Adding – For adding a row, left click on the row number at the far right side of the worksheet that is immediately below the place where you would like to add a row. For adding a column, left click on the column number at the top of the worksheet that is immediately to the right of the place where you would like to add a column. This should highlight the entire row or column. Keeping the cursor over this number, right click on the mouse and a drop box will appear. Select “insert” to add the new row or column. The new row or column will have the same formatting (colors and lines) that are in the proceeding column or row.

Deleting – Left click on the row number at the far right side of the worksheet, or the column number at the top of the worksheet that is to be deleted. This should highlight the entire row or column. Keeping the cursor over this number, right click on the mouse and a drop box will appear. Select “delete” to remove the entire row or column.

Comment Pop-up Boxes

A small red triangle in the upper right corner of a cell indicates a comment box that contains notes. Some of these notes are lists that the user should edit and add to.

Viewing – The comment box will appear by passing the mouse cursor over the red triangle. ***To retain view*** of the comment box after the mouse has moved to another cell, first view the comment box by passing the mouse over the red triangle, then single click the right mouse button, another pop-up box will appear, click on “show comment”. ***To remove the retained view*** of a comment box, left-click on the worksheet cell the box is coming from, then right-click, another pop-up box will appear, click on "Hide comment".

Editing – To edit the contents of a comment pop-up box, move the mouse over the cell, left click on the mouse to select the cell, then right click and select “edit comment” on the pop-up menu. Move the cursor around in the box and make desired edits. When done, move the mouse cursor off the comment box and left click on the mouse.

Creating – To create a comment box in a cell that does not already have one, move the mouse over the cell, left click on the mouse to select the cell, then right click and select “insert comment” on the pop-up menu. A comment box will appear. The contents of another comment box can be cut and pasted into the new comment box. Fonts can be changed using the “format” tab (at the top of the page) while editing the box. A comment box can be ***copied*** by cutting and pasting the entire cell, or by copying the comment box contents in “edit comment box”, and then pasting this into a newly created comment box. (Note: this later method will not retain the original comment box fonts.)

2.0 Worksheet 2 -- Essential Services

Worksheet 2 contains a template for assessment of criticalities that may arise in essential services as a result emergency response effects on traffic patterns. This worksheet may be copied for use in new scenarios. The top rows of Worksheet 2 provide space for users to fill in the objectives received from the Incident Command (IC) during an emergency event. Under each of these objectives, the user is to fill in the actions that have been taken to fulfill these objectives. This list of actions is to be considered throughout the use of this worksheet during an exercise or event to track the effects of changes in traffic patterns on essential services.

Many of the column headers on this worksheet have comment boxes (indicated by small red triangles in the upper left corner of the cell) that contain notes describing what should be entered in the cells below. Comments boxes are also attached to some of the cells in the rows below the header rows–these comment boxes are for notes and lists to be edited and created by the user. Section 4.0 provides views of the Essential Services Worksheet completed for several hypothetical scenarios.

2.1 Essential Services List (Column A)

This column lists categories of essential services that may be affected by changes in traffic patterns. This is an example list of services that are essential for community sustenance and health. It should be modified by the user to better reflect their community, and updated as needed. The example “Essential Service” categories of **Column A** are listed in **Table 2**.

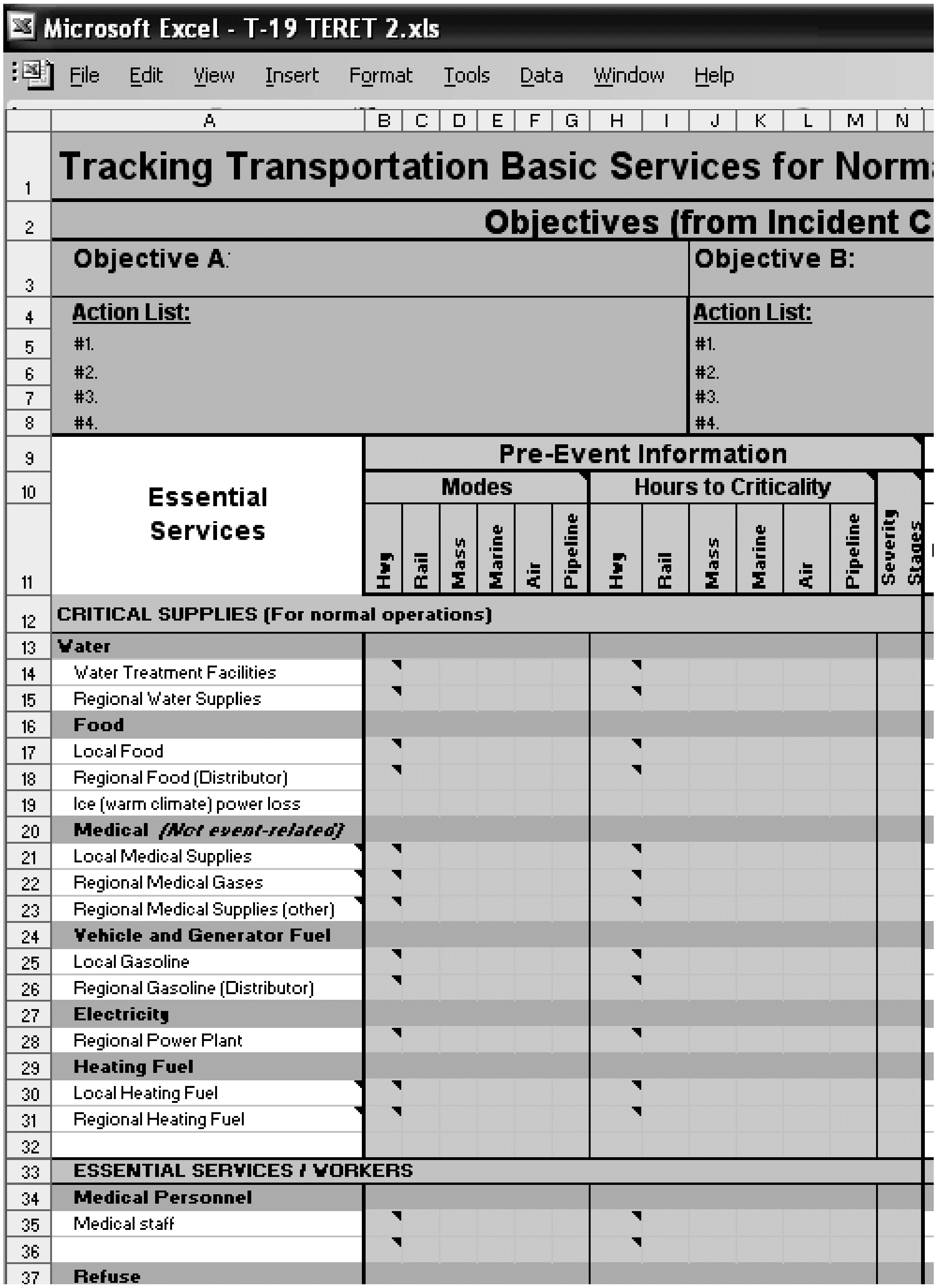
Table 2. Essential Service (Column A) Categories

Column A: Essential Services	Description
Critical Supplies	
Water	■ Local water treatment facilities ■ Regional water treatment chemical suppliers
Food	■ Local food suppliers (retail) ■ Regional food distributors or producers
Medical	■ Local medical supplies at pharmacies, hospitals, medical centers, etc. ■ Regional distributors and manufacturers of medical supplies
Vehicle/ Generator Fuel	■ Local retail gasoline and diesel supplies ■ Regional distributors of gasoline and diesel fuel
Electricity	■ Local power transfer stations ■ Regional power plants
Heating Fuel	■ Heating fuel suppliers to local end-users ■ Heating fuel suppliers to distributors and/ or regional end-users.
Essential Workers/ Service	
Medical personnel	🕑 ■ Commuting of medical personnel
Refuse	🕑 ■ Transport of refuse

2.2 Pre-Event Information (Columns B through N)

Information in the pre-event columns (**Figure 2**) is collected from discussion with the essential service providers representing the services (and supplies) listed in **Column A**. As this information is collected and periodically updated, the Contacts worksheet (Worksheet 4) should be concurrently updated. Note: these columns are not the only ones that require pre-event information–the comment boxes under “Hours to Solve” (**Columns S, W, and AA**, addressed in Section 2.3) should also be completed as prior to an event or an exercise

Figure 2. A View of the Pre-Event Information Columns in TERET Worksheet 2.



	A	B–G	H–M	
1	Tracking Transportation Basic Services for Norm			
2	Objectives (from Incident C			
3	Objective A:		Objective B:	
4	Action List:		Action List:	
5	#1.		#1.	
6	#2.		#2.	
7	#3.		#3.	
8	#4.		#4.	
9	Essential Services	Pre-Event Information		
10		Modes	Hours to Criticality	
11		Hwy Rail Mass Marine Air Pipeline	Hwy Rail Mass Marine Air Pipeline	Severity Stages
12	CRITICAL SUPPLIES (For normal operations)			
13	Water			
14	Water Treatment Facilities			
15	Regional Water Supplies			
16	Food			
17	Local Food			
18	Regional Food (Distributor)			
19	Ice (warm climate) power loss			
20	Medical *(Not event-related)*			
21	Local Medical Supplies			
22	Regional Medical Gases			
23	Regional Medical Supplies (other)			
24	Vehicle and Generator Fuel			
25	Local Gasoline			
26	Regional Gasoline (Distributor)			
27	Electricity			
28	Regional Power Plant			
29	Heating Fuel			
30	Local Heating Fuel			
31	Regional Heating Fuel			
32				
33	ESSENTIAL SERVICES / WORKERS			
34	Medical Personnel			
35	Medical staff			
36				
37	Refuse			

- **Modes (Columns B though G) --** For each row (i.e., essential service), indicate the transportation modes that provide final deliveries of supplies or personnel access with “1”. Indicate mode(s) that feed these modes within your region with a 2. If there is a feeder to the feeder mode in your region, indicate it with a 3. Add notes in these cell comment boxes as needed to help explain the transportation of these supplies or services, and indicate potential alternative routes.

! **Pre-Event Information**

Modes -- *these vary both among communities and over time.*

- **Hours to Criticality (Columns H through M) --** A “criticality” is an exhaustion of supplies or shortage of service that may have serious consequences in terms of human health or sustenance. For each essential service, the time to “criticality” is estimated as the shortest “hours to criticality” based on typical minimum supplies, or maximum time that shift workers can be held overtime.

  These estimates only apply to the modes that are involved in each essential service. Thus, for each row, the modes that provide final deliveries and feeder modes as indicated in **Columns B through G** should have an “hours to criticality” estimates entered in **Columns H though M**. The same essential service may have different hours to criticality at local and regional levels as a result of different storage capabilities. For these cases, local and regional services should be listed on separate rows.

! **Pre-Event Information**

Time to Criticality -- *these vary both among communities and over time.*

To provide an easy check for use during an emergency, the user should edit the comment boxes of the cells in this column to list the possible criticalities and their direct impact for each row (e.g., loss of drinking water and diseases from poor water quality; or extreme worker fatigue and unacceptable level of medical errors). The box below provides an example of cell entry for modes and hours to criticality.

Example: Pre-Event Criticality Information – Modes and Hours to Criticality

A water treatment plant may receive chlorine gas shipment by truck (highway) every week, and if a delivery does not occur, chlorine supplies will be exhausted within 1 to 2 days of the missed delivery. Thus, the minimum time to criticality is entered as 24 hours, and there may be no alternative delivery modes, only alternative routes. Some alternative routes may be included in the comment box for this cell. The chlorine comes from a regional supplier that received their shipments by rail. Based on normal delivery rates, the regional supplier will exhaust their supply of chlorine within 72 hours if rail shipment is lost. For the regional supplier, the highway mode could provide alternative deliveries, and this should be stated in the comment box for this cell. During an exercise or actual event, the plant operator could be contacted to update this estimate, which may be longer if they have just received a shipment, or may be shorter if they have had atypical storage, delivery, or demand issues.

- **Severity Level (Column N) --** This column is to rank the seriousness of a criticality caused by a transportation-related action in a “worst case scenario”. Ranking may be based on projected deaths, injury, economic damages, etc. Some examples possible severity level ranks are shown in **Table 3**.

Table 3. Examples of Severity Level Rankings

Example 1	Example 2
3 = more than 1,000 hospital patients	4 = deaths exceed 1,000
2 = 101 to 1,000 hospital patients	3 = deaths from 100 to 1,000
1 = 0 to 100 hospital patients	2 = deaths from 10 to 100
	1 = deaths from 1 to 10

Users should establish their own ranking system based on their priorities to better focus their attention during an emergency event or exercise.

2.3 Affected Zones (Columns O through AA)

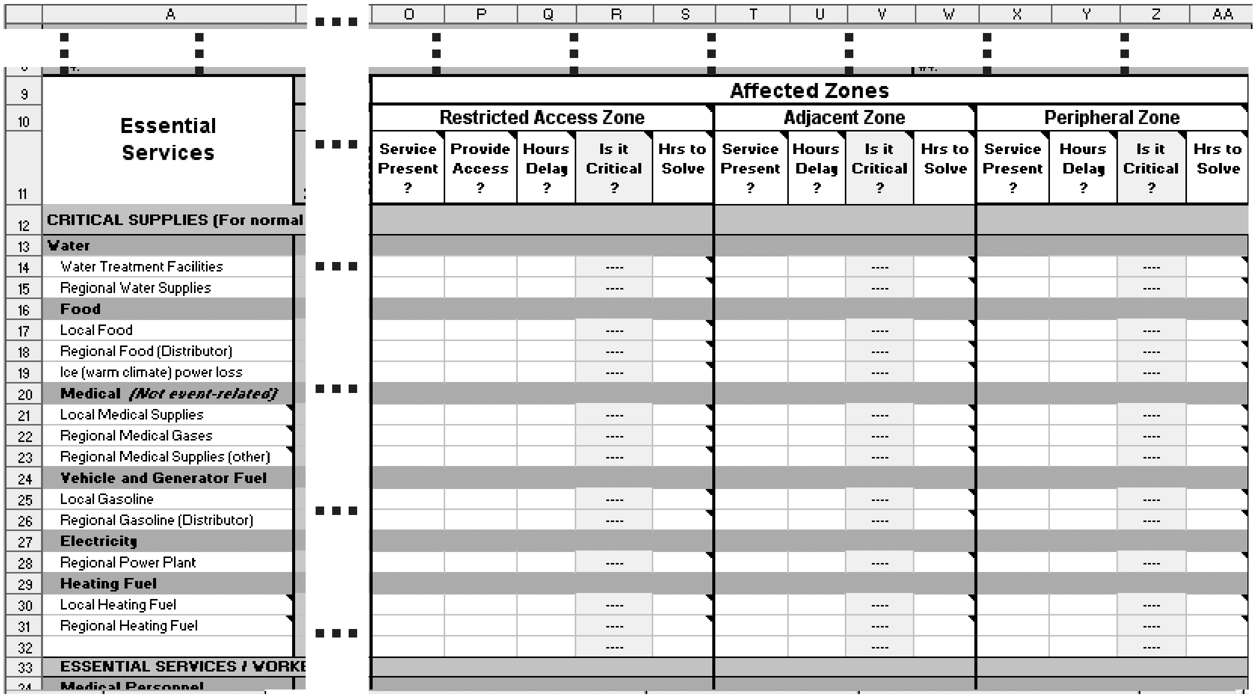
Transport delays due to emergency response activities vary with distance from the incident area. TERET allows the user to assess the effects of these changes in traffic patterns in three general zones (**Figure 3**):

1. **Restricted Zone (Columns O through S)** – areas with restricted access as designated by the incident command. Egress may or may not be restricted depending on whether the objective is to evacuate, shelter-in-place, or quarantine. Transportation on some modes and/or routes will likely be suspended.

2. **Adjacent Zone (Columns T through W)** – areas surrounding the restricted zone where travel time may be increased as a result of altered traffic patterns to provide detours around the restricted zone, resource reallocations to enable objectives such as evacuation, and to facilitate first-responder access to the restricted zone. Some transportation may be suspended in this zone (e.g., hazmat shipments).

3. **Peripheral Zone (Columns X through AA)** – areas surrounding the adjacent zone. While traffic patterns and travel time are generally less affected in this zone, criticalities may arise when critical resources for the peripheral zone are located in the restricted or adjacent zone, and when there has been substantial resource reallocation to the restricted and adjacent zones. The peripheral zone may be contained entirely within a state or region, or it may be expanded to include nationwide transportation. During events that cause nationwide increases in the Department of Homeland Security (DHS) threat advisory levels (i.e., to orange or red), transportation delays across the nation may substantially affect deliveries of critical supplies.

Figure 3. A view of the Affected Zones Columns on TERET Worksheet 2.



	A	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
9	**Essential Services**	**Affected Zones**												
10		**Restricted Access Zone**					**Adjacent Zone**				**Peripheral Zone**			
11		**Service Present ?**	**Provide Access ?**	**Hours Delay ?**	**Is it Critical ?**	**Hrs to Solve**	**Service Present ?**	**Hours Delay ?**	**Is it Critical ?**	**Hrs to Solve**	**Service Present ?**	**Hours Delay ?**	**Is it Critical ?**	**Hrs to Solve**
12	**CRITICAL SUPPLIES (For normal**													
13	**Water**													
14	Water Treatment Facilities				----				----				----	
15	Regional Water Supplies				----				----				----	
16	**Food**													
17	Local Food				----				----				----	
18	Regional Food (Distributor)				----				----				----	
19	Ice (warm climate) power loss				----				----				----	
20	**Medical** ***(Not event-related)***													
21	Local Medical Supplies				----				----				----	
22	Regional Medical Gases				----				----				----	
23	Regional Medical Supplies (other)				----				----				----	
24	**Vehicle and Generator Fuel**													
25	Local Gasoline				----				----				----	
26	Regional Gasoline (Distributor)				----				----				----	
27	**Electricity**													
28	Regional Power Plant				----				----				----	
29	**Heating Fuel**													
30	Local Heating Fuel				----				----				----	
31	Regional Heating Fuel				----				----				----	
32					----				----				----	
33	**ESSENTIAL SERVICES / WORKE**													
34	**Medical Personnel**													

Event-specific information is entered in the "Affected Zones" columns during emergency response and recovery. This includes the following:

- **Columns O, T, and X: Service Present?** – User entry for this column is either YES or NO, using capital letters. This cell entry is to answer the question: Is this essential service located in this zone?
- **Column P: Provide Access? --** User entry for this column is either YES, or NO, using capital letters. This cell entry is to answer the question: Is this essential service (listed in **Column A**) to have access to the restricted zone? In the restricted zone, some essential services may be suspended if the population has evacuated. During shelter-in-place scenarios, many services may need access and egress to prevent criticalities. In other scenarios, certain types of shipment (i.e., Hazmat) may be suspended.
- **Columns Q, U, and Y: Hours Delay? --** User entry for these columns is the estimated delay in deliveries of critical supplies and transport of critical personnel needed for the essential services provided by this row category (listed in **Column A**). Delay estimates are often given as a range. In these cases, the upper boundary of the range should be entered. Thus, if a 12 to 24 hour delay in deliveries is expected, delay hours should be entered as 24.
- **Columns R, V, and Z: Is it Critical? --** This column (shaded in yellow) automatically generates "YES" if the "hours delay" in this zone equals or exceeds the "hours to criticality" for any mode. "NO" is generated if "hours delay" is less than the "hours to criticality" for all modes, and dashes (i.e., ----) are generated when no hours delay have been entered. In the Restricted Zone (**Column R**), "no access" is generated if "NO" has been entered in **Column P** as answer to the question "Provide Access".

Note that this rough assessment of a criticality is based on the *a priori* estimation of the time an essential service can function without new deliveries assuming a delivery is due (and delayed) on the day the incident occurs. If no critical shipments were expected on the day of the incident, the time to criticality may be longer than the estimate. Thus, for essential services that do not receive critical shipments every day, the essential service provider should be contacted to adjust the hour to criticality as appropriate for the specific scenario.

- **Columns S, W, and AA: Hours to Solve –** Comment boxes for these cells should be completed as pre-event information. Data entry for the cell box is entered during an exercise or event.

  Prior to an exercise or event, the user should edit the comment boxes for these cells to provide a list of possible solutions for provision of critical transportation services to the essential service indicated in **Column A**. The purpose of this list is to provide a quick checklist of possible options, thus it may include solutions that may only be viable under some scenarios. The list of possible solutions may be the same for each of the zones, and the comment box contents can be copied between these columns.

  During an exercise or event, the user should examine each row, and if the previous column is "YES" (it is critical), the user should edit the cell contents under "Hours to Solve" to indicate estimated hours to implement a solution to prevent or minimize a criticality. This time estimate should be determined from discussions with field personnel.

! **Pre-Event Information**

Hours to Solve Comment boxes – *These lists of possible solutions for delays may change over time.*

2.4 Essential Services Contacts (Column AB) and the Contacts Worksheet

For each essential service listed in **Column A**, the general category of the contact person for pre-event information should be listed in **Column AB.** By clicking on the tab for the Contacts Worksheet (at the bottom of the worksheet), the list of all contacts is displayed. (Note: the user may prefer to use other contact management software.)

The **Contacts Worksheet** column labeled **"Contact Category"** (Column A), allows organization of contact information based on categories rather than names of individuals or organizations. This allows users who are not readily familiar with all contacts to quickly find the information needed based on the information category.

! **Pre-Event Information**

*The **Contact List** developed by the user, will need frequent updating to be helpful.*

The user is encouraged to re-organize the remaining columns in the Contacts Worksheet to best meet their preferences. These column headers are for standard contact information (i.e., **Name, Organization, Address, E-mail, Telephone, etc.**) and additional information essential for maintaining good records of information sources. This includes a column labeled **"Notes"**, to be used for more detailed information on the contacts or recent communications. The column labeled **"Date"** should be used to track when information is received from the contact. Maintaining a dated record of these contacts is very important both for rapid recognition of more and less recent information during an event or exercise, and for post-event assessments of information handling.

2.5 Command Chain Contacts (Column AC)

Command Chain Contacts (Column AC) should be notified as soon as it is recognized that a critical situation may arise in an essential service under the current conditions, considering the mitigation ability of the user. The greater the lead time provided on potential criticalities, the greater the chance of mitigating or preventing the critical situation. For some users, the command chain contact may be the same for all criticalities, e.g., the Emergency Operation Center (EOC) Logistics Chief.

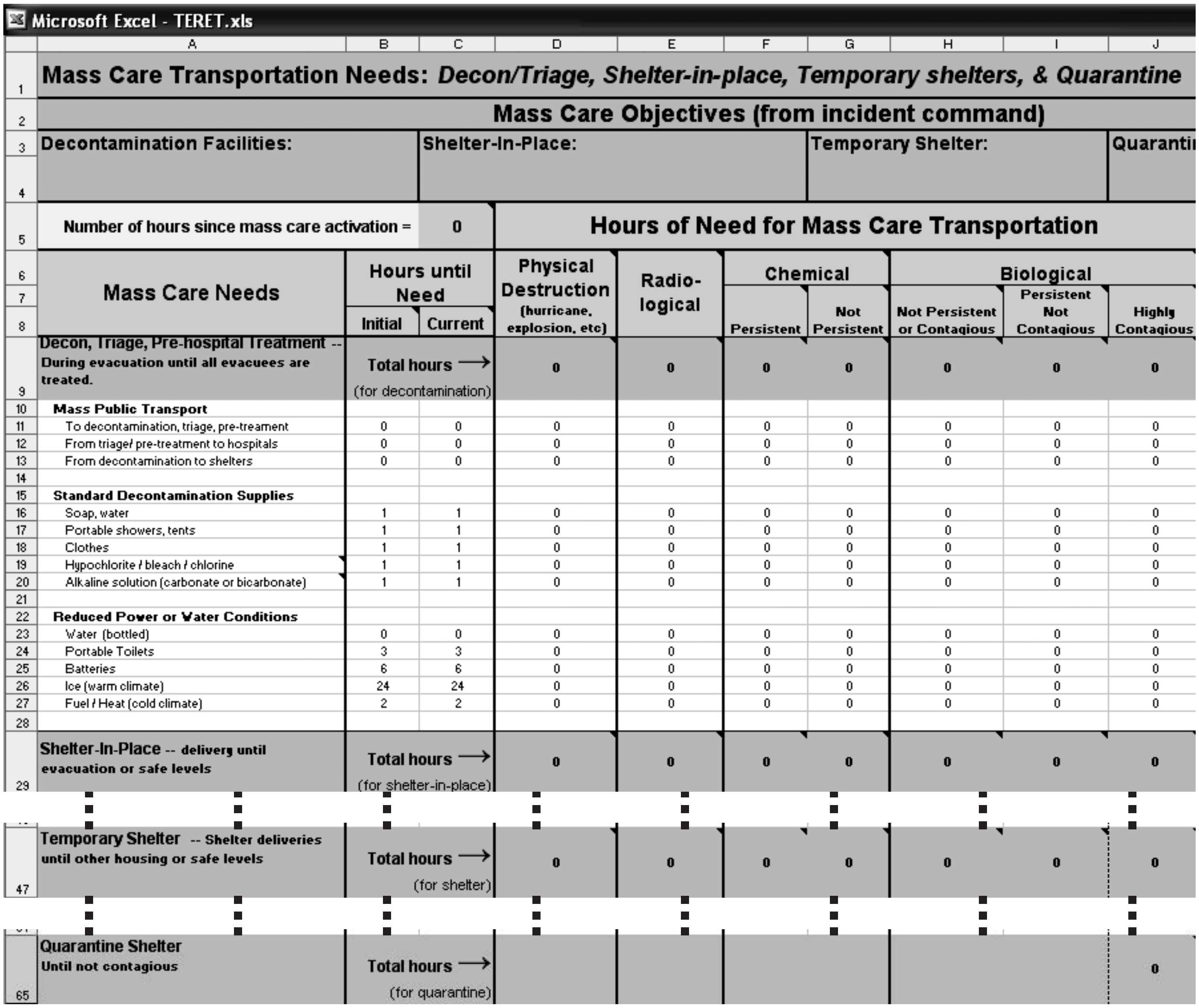
! **Pre-Event Information**

Command Chain Contacts *should be identified before an event*

3.0 Worksheet 3: Mass Care

The top rows of Worksheet 3 provide space for users to fill in the mass care shelter objectives received from Incident Command (IC) during an emergency event. These possible objectives include decontamination and medical care, shelter-in-place, temporary shelter, and quarantine shelter. In terrorism events (known or suspected), the FBI may require screening of evacuees which may add to the time people are held at exit points such as decontamination sites. Note that evacuation does not require mass care needs in itself, but only as decontamination and medical care sites, and temporary shelters are established in response to evacuation. Thus, this worksheet addresses transport of people to mass care facilities, but does not address self-evacuation to places other than mass care facilities. **Figure 4** shows **Columns A** through J of this worksheet.

Figure 4. A View of TERET Worksheet 3.



	A	B	C	D	E	F	G	H	I	J
1	**Mass Care Transportation Needs:** ***Decon/Triage, Shelter-in-place, Temporary shelters, & Quarantine***									
2	**Mass Care Objectives (from incident command)**									
3	**Decontamination Facilities:**		**Shelter-In-Place:**				**Temporary Shelter:**			**Quaranti**
4										
5	Number of hours since mass care activation =		0	**Hours of Need for Mass Care Transportation**						
6	**Mass Care Needs**	**Hours until Need**		**Physical Destruction** (hurricane, explosion, etc)	**Radio-logical**	**Chemical**		**Biological**		
7									Persistent Not Contagious	
8		**Initial**	**Current**			**Persistent**	**Not Persistent**	**Not Persistent or Contagious**		**Highly Contagious**
9	**Decon, Triage, Pre-hospital Treatment** -- During evacuation until all evacuees are treated.	**Total hours** ⟶ (for decontamination)		0	0	0	0	0	0	0
10	**Mass Public Transport**									
11	To decontamination, triage, pre-treament	0	0	0	0	0	0	0	0	0
12	From triage/ pre-treatment to hospitals	0	0	0	0	0	0	0	0	0
13	From decontamination to shelters	0	0	0	0	0	0	0	0	0
14										
15	**Standard Decontamination Supplies**									
16	Soap, water	1	1	0	0	0	0	0	0	0
17	Portable showers, tents	1	1	0	0	0	0	0	0	0
18	Clothes	1	1	0	0	0	0	0	0	0
19	Hypochlorite / bleach / chlorine	1	1	0	0	0	0	0	0	0
20	Alkaline solution (carbonate or bicarbonate)	1	1	0	0	0	0	0	0	0
21										
22	**Reduced Power or Water Conditions**									
23	Water (bottled)	0	0	0	0	0	0	0	0	0
24	Portable Toilets	3	3	0	0	0	0	0	0	0
25	Batteries	6	6	0	0	0	0	0	0	0
26	Ice (warm climate)	24	24	0	0	0	0	0	0	0
27	Fuel / Heat (cold climate)	2	2	0	0	0	0	0	0	0
28										
29	**Shelter-In-Place** -- delivery until evacuation or safe levels	**Total hours** ⟶ (for shelter-in-place)		0	0	0	0	0	0	0
47	**Temporary Shelter** -- Shelter deliveries until other housing or safe levels	**Total hours** ⟶ (for shelter)		0	0	0	0	0	0	0
65	**Quarantine Shelter** Until not contagious	**Total hours** ⟶ (for quarantine)								0

3.1 Mass Care Needs and Hours until Need (Columns A through C)

As described below, pre-event information in required in **Column B**, and other entries are made during an exercise or event.

Cell C5: Number of Hours since Mass Care Activation – During and exercise or event, the user should enter the number of hours that has elapsed since opening mass care sites, and update this number as response and recovery continue.

> **Attention!**
>
> *Cell C5 should be frequently updated during an event because it is used to calculate the number of remaining hours for mass care needs.*

Mass Care Needs Column A -- This column provides an example list of essential mass care transportation-dependent needs related to decontamination, triage, and pre-hospital treatment (**Rows 10 to 28**); shelter-in-place locations (**Rows 30 to 46**); temporary shelters (**Rows 48 to 64**); and quarantine shelters (**Rows 66 to 82**). These are divided into “Standard Needs” that are always required, and additional needs that may be required during “Reduced Power or Water Conditions” (e.g., **Column A, Lines 22 to 27**).

Column B: Initial Hours until Need – In this column, enter the estimated number of hours from the designation of mass care sites until the supplies and services listed in **Column A** will be needed. These estimates should be developed based on pre-event discussions with local and regional mass care agencies. The “contact category” for this information should be listed in **Column K** of these rows to facilitate rapid location of the contact information *(see Section 3.3, below)*.

> ! **Pre-Event Information**
>
> ***Initial Hours until Need*** *for a mass care site to receive supplies, etc.*

Column C: Current Hours until Need -- This column contains an automatic calculation of hours remaining until the listed supplies and services are needed, based on the user entry of “initial hours to need” (**Column B**) and “Number of hours since mass care activation” (**Cell C5**).

3.2 Hours of Need for Mass Care (Columns D through J)

Each of these columns is for a different type of event. These events types include physical destruction (e.g., hurricane, explosion, etc.), radiological releases, chemical releases, or biological releases. Chemical events are divided into two categories: persistent and not persistent, while biological events are divided into three categories based on both persistence and contagiousness. These sub-categories for chemical and biological event are based on essential characteristics of the event that will affect the response and associated mass care needs. Comment boxes associated with the headers of these columns provide some notes on the types of threats that fall in these categories the types of medical care that may needed. The report produced as another part of this project (described in the Preface) provides additional information on chemical, biological, and radiological threats and their relationship to the transportation system.

"Total Hours" of site activation (Rows 9, 29, 47, and 65) -- The user should enter in these rows (**Columns D through J)** the period of time, or duration, during which mass care sites will be required. For general planning purposes, an emergency management office may be able to provide some estimates of typical expected shelter times during some types of events, but any entry of these numbers should be adjusted on an event-specific basis, and may be readjusted as more accurate information becomes available.

During an exercise or event, these estimates should be obtained from the command chain, typically within the Emergency Operations Center (EOC). These estimates will likely to need modification as response to the event proceeds.

Note that when there is only one type of threat, only one of the **Columns D through J** will need to have numbers.

! **Pre-Event Information**

*Identify the contact person who will provide estimates of **"Total Hours"** of site activation*

Remaining hours of transportation-dependent mass care needs (Rows 10 to 28, 30 to 46, 48 to 64, and 66 to 81) -- The un-shaded rows in **Columns D to J** (located below the shaded rows for "Total Hours" of site activation) automatically calculate the number of hours for which mass care transportation will be needed. This calculation is based on the difference between the estimated "Total hours" of site activation (**Rows 9, 29, 47, and 65**); "Initial hours until need" (**Column B**); and the "Number of hours since mass care activation" (**Cell C5**).

3.3 Mass Care Contacts (Column K) and the Contacts Worksheet

For each "Mass Care Need" listed in **Column A**, the general category of the contact person for pre-event information should be listed in **Column K.** By clicking on the tab for the Contacts Worksheet (at the bottom of the worksheet), the list of all contacts is displayed.

The **Contacts Worksheet** column labeled "**Contact Category**" (**Column A**), allows organization of contact information based on categories rather than names of individuals or organizations. This allows users who are not readily familiar with all contacts to quickly find the information needed based on the information category.

! **Pre-Event Information**

Contact Lists -- *developed by the user, need frequent updating to be helpful.*

The user is encouraged to re-organize the remaining columns in the Contacts Worksheet to best meet their preferences. These column headers are for standard contact information (i.e.,

Name, Organization, Address, E-mail, and Telephone) and additional information essential for maintaining good records of information sources. This includes a column labeled “**Notes**”, to be used for more detailed information on the contacts or recent communications. The column labeled “**Date**” should be used to track when information is received from the contact. Maintaining a dated record of these contacts is very important both for rapid recognition of more and less recent information during an event or exercise, and for post-event assessments of information handling.

3.4 Command Chain Contact (Column K, Rows 5 to 8)

A **Command Chain Contact** that can provide estimates of the total hours that mass care sites may be activated should be identified prior to an exercise or event. This contact will likely be someone at the Emergency Operations Center (EOC).

! **Pre-Event Information**

***Command Chain Contacts** should be identified before an event*

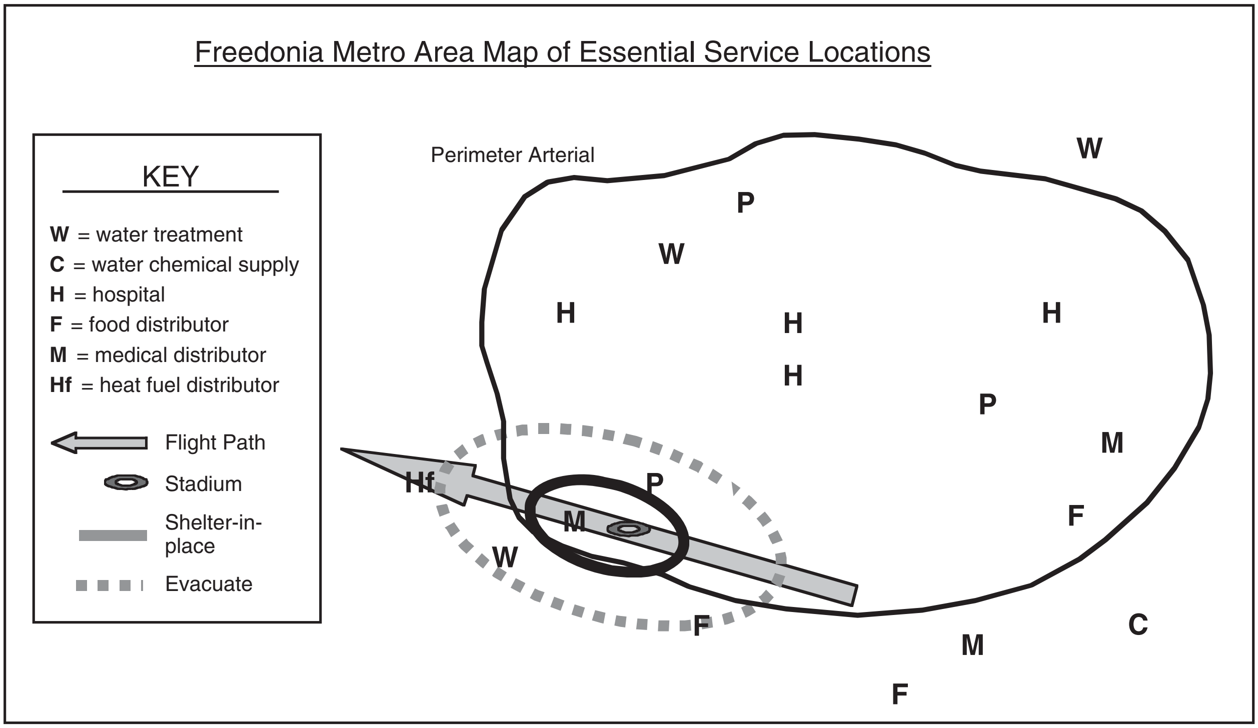
4.0 Threat-Specific Scenarios

From a functional perspective, TERET is an all-hazards tool that may be applied during any large emergency event, regardless of cause, size, or complexity. It is designed to work under the Incident Command System in support of the National Incident Management System. This section presents three threat scenarios for terrorist attacks: a chemical attack, biological attack, and radiological attack. These scenarios are similar to planning scenarios that have been developed by the DHS. As shown below, the scenarios exemplify the varied transportation effects that may be identified with TERET use. Each scenario is briefly described below and followed by views of completed example worksheets.

4.1 Scenario 1: Chemical Attack (Blister Agent)

On a chilly autumn day with very little wind, a light aircraft sprays a mist of garlic-smelling “oi” over Freedonia University’s outdoor stadium during the season playoffs. The stadium is immediately contaminated with the substance, along with surrounding areas including parking lots, an arterial, and a mass transit station. The crowd panics and evacuates the stadium within 30 minutes. First-responders arrive in 10 minutes, after some stadium evacuees have already driven out of the parking lot. There are immediate reports of respiratory and eye irritations, and within minutes, there are reports of stinging skin pain. Hazmat team detection kits identify the chemical mixture of Lewisite and sulfur mustard. Shelter-in-place is ordered based on the plane’s observed flight path within roughly a 1/2 mile of the stadium, and evacuation from 1/2 to 1 mile, see **Figure 5**. Decontamination and triage sites are established for stadium evacuees and rapid transportation to hospitals for critical injuries. A moratorium is placed on regional Hazmat shipments.

Figure 5. Scenario #1 -- Schematic Presentation of a Chemical Attack Area



When the evacuation from 1/2 to 1 mile is near complete (approximately 3 hours), first-responders begin systematic, assisted evacuation of the shelter-in-place zone, which takes approximately 48 hours. Cool temperatures and low winds retard natural volatilization and degradation, causing projections of the hazardous levels on surfaces to last for 8 to 12 weeks without active decontamination. Decontamination of the stadium, arterial, mass transit station, and other contaminated areas can be achieved with application of bleach solutions, but chlorine runoff poses serious environmental concerns and active decontamination efforts are delayed while technical options are assessed and means for runoff collection are constructed.

The TERET Essential Services worksheets shown in **Figures 6** and **7**, has been filled in for this hypothetical scenario. **Figure 6** displays some of the notes the user made in comment boxes to better guide their actions. **Rows 3 through 8** contain the objectives from Incident Command and a brief summary of the transportation actions taken to achieve these actions. Based on a map of the restricted zone, see **Figure 5**, essential services located in the restricted zone are indicated with a “YES” in **Column O**. For each service provider in this zone that provides an essential service to areas beyond the restricted zone, a new row was created to better track the effects of the delayed or suspended service from these providers. The adjacent zone is considered as the entire Freedonia Metropolitan Area. The duration of the moratorium on Hazmat shipments is estimated as 10 days, thus 240 (hours) has been entered for water treatment chemical delays (Row 16) in the adjacent zone. The moratorium on Hazmat shipments does not extend to the peripheral zone.

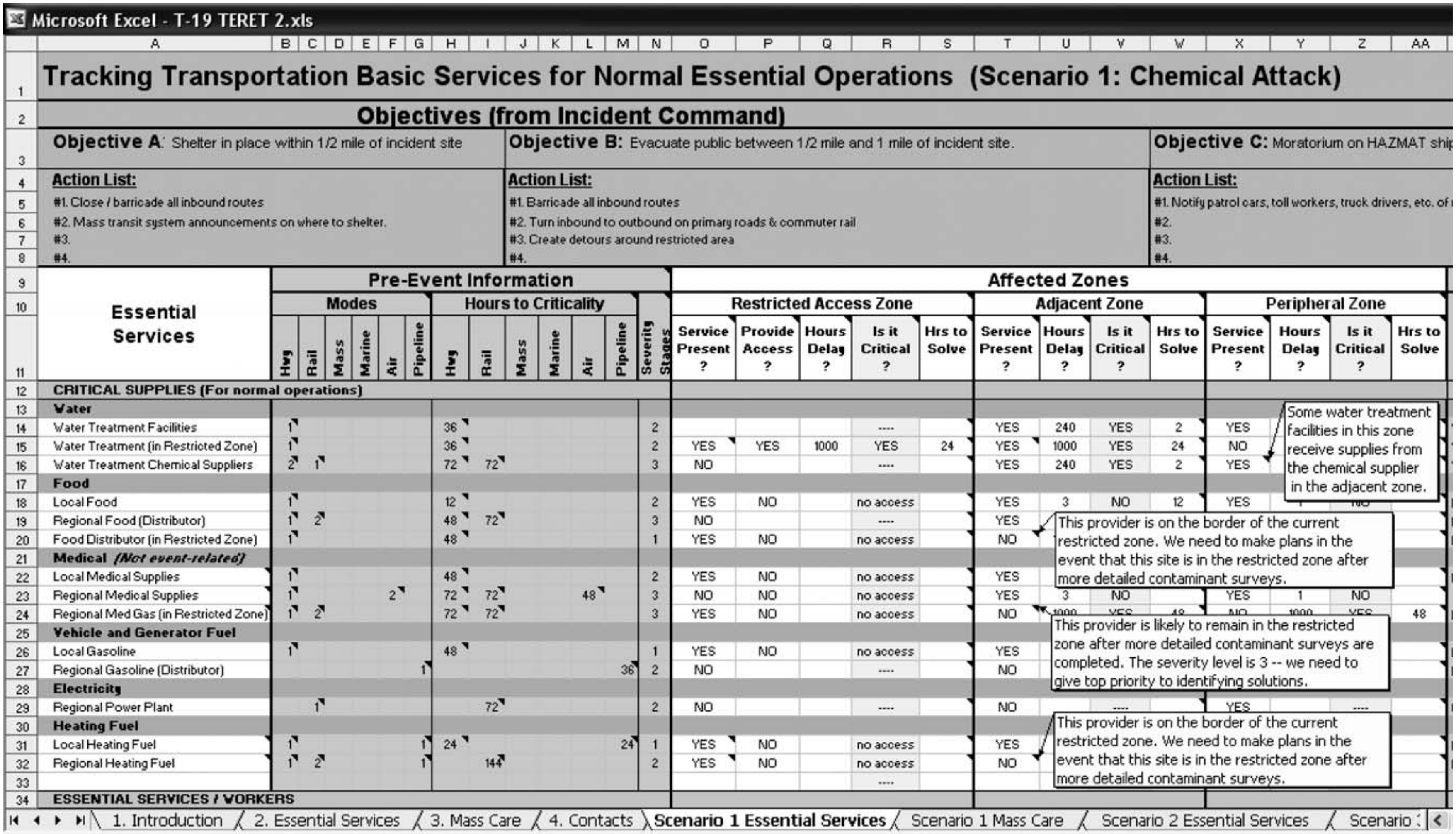
In the restricted zone, the Incident Command has determined that access should be provided for operation of the water treatment plant, recognizing that the water treatment process will destroy the blister agent contaminants, and water will likely be needed for decontamination of other areas in this zone, not to mention the effects of loss of potable water on the adjacent zone population served by this plant. After discussions with the water treatment chemical supplier and their command chain contact, the user determined that appropriate waivers and plans for dealing with the contaminated truck after deliveries in the restricted zone would cause no more than a 24 hour delay. Similar accommodations will be made for any necessary maintenance at the local power transfer station in the restricted zone. Remaining services in the Restricted Zone are not further considered because these services are not needed for the evacuated population, and access for them was not designated by Incident Command, as indicated in **Column P** as answer to the question: “Provide access”.

In the adjacent zone, notes have been made in the comment boxes of **Column T** (“Service Provided”) regarding regional suppliers that are either in or near the restricted zone, see **Figure 6**. General transportation delays in the adjacent zone are estimated to be up to 3 hours, primarily due to the closure of nearly a quarter of the perimeter arterial and detours and related congestion around the restricted zone. At this stage of response to this event, a detailed contaminant survey is pending, thus the exact borders of the restricted zone are expected to shift soon. Potential criticalities in the adjacent zone, indicated by “YES” in **Column V**, include water, medical supplies, food, and electricity that are provided by suppliers in the restricted zone. Solutions for water and electricity in the restricted zone will allow timely provision of these services to the adjacent zones. For food and heating fuel supplies that are delivered to the adjacent zone from the restricted zone, agreements have been made with suppliers in other regions to provide alternative sources of these supplies. The greater distance of these suppliers will cause some delays (as entered in **Cells W20, W24, and W32**), but a visual comparison of the “Hours to Solve” (**Column W**) to the “hours to criticality” (**Columns H through M**) suggests that these potentially critical conditions can be avoided with good communication regarding supply needs and alternative routes. The moratorium on Hazmat shipments will affect the regional water chemical supplier (**Cell U16**) and the deliveries to water treatment facilities (U14). However, a waiver can prevent this criticality, which will take no more than 2 hours, as indicated in **Cell W14 and W16**. This entry does not include the general 3 hour delay expected for deliveries within the adjacent zone, but together, these delays are still substantially less than the hours to criticality (**Column H and I**).

In the peripheral zone, some water treatment facilities receive chemicals from the water chemical supplier in the adjacent zone, thus potential hours delay are the same as the duration of the moratorium on Hazmat shipments in the adjacent zone. As in the adjacent zone, this criticality can be averted with waivers. The peripheral zone is also is projected to be affected by suspended service from the medical supplier in the restricted zone (indicated in **Cell Y24**), however, as in the adjacent zone, suppliers in other regions should be able to provide similar supplies before critical conditions are reached.

The TERET Mass Care worksheet is shown in **Figure 8**, has been filled in for this hypothetical example. Pre-event information was already in **Columns B and C**. The user enters the current number of hours since mass care sites were established in **Cell C5**. This incident involves the release of persistent chemicals with no other threat categories, thus the user provides estimates obtained from incident command on the number of hours that decontamination and triage sites are expected to be needed in **Cell F9**. This entry leads to an automatic estimation of the duration transportation is needed at these sites in **Cells F11 to F27**. Similarly, an estimate from incident command on the duration temporary shelters will be needed is entered in **Cell F29** for automatic estimation of the duration transportation is needed for temporary shelters.

Figure 6. View of the Essential Services Worksheet for Scenario 1, With Some Comment Boxes Displayed.



Tracking Transportation Basic Services for Normal Essential Operations (Scenario 1: Chemical Attack)

Objectives (from Incident Command)

Objective A: Shelter in place within 1/2 mile of incident site

Action List:
#1. Close / barricade all inbound routes
#2. Mass transit system announcements on where to shelter.
#3.
#4.

Objective B: Evacuate public between 1/2 mile and 1 mile of incident site.

Action List:
#1. Barricade all inbound routes
#2. Turn inbound to outbound on primary roads & commuter rail
#3. Create detours around restricted area
#4.

Objective C: Moratorium on HAZMAT shi

Action List:
#1. Notify patrol cars, toll workers, truck drivers, etc. of
#2.
#3.
#4.

Essential Services	Pre-Event Information													Affected Zones												
	Modes						Hours to Criticality							Restricted Access Zone					Adjacent Zone				Peripheral Zone			
	Hwy	Rail	Mass	Marine	Air	Pipeline	Hwy	Rail	Mass	Marine	Air	Pipeline	Severity Stages	Service Present ?	Provide Access ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve
CRITICAL SUPPLIES (For normal operations)																										
Water																										
Water Treatment Facilities	1						36						2				----		YES	240	YES	2	YES			
Water Treatment (in Restricted Zone)	1						36						2	YES	YES	1000	YES	24	YES	1000	YES	24	NO			
Water Treatment Chemical Suppliers	2	1					72	72					3	NO			----		YES	240	YES	2	YES			
Food																										
Local Food	1						12						2	YES	NO		no access		YES	3	NO	12	YES			
Regional Food (Distributor)	1	2					48	72					3	NO			----		YES							
Food Distributor (in Restricted Zone)	1						48						1	YES	NO		no access		NO							
Medical *(Not event-related)*																										
Local Medical Supplies	1						48						2	YES	NO		no access		YES							
Regional Medical Supplies	1				2		72	72			48		3	NO	NO		no access		YES	3	NO		YES	1	NO	
Regional Med Gas (in Restricted Zone)	1	2					72	72					3	YES	NO		no access		NO	1000	YES	48	NO	1000	YES	48
Vehicle and Generator Fuel																										
Local Gasoline	1						48						1	YES	NO		no access		YES							
Regional Gasoline (Distributor)						1						36	2	NO			----		NO							
Electricity																										
Regional Power Plant		1						72					2	NO			----		NO		----		YES		----	
Heating Fuel																										
Local Heating Fuel	1					1	24					24	1	YES	NO		no access		YES							
Regional Heating Fuel	1	2				1		144					2	YES	NO		no access		NO							

ESSENTIAL SERVICES / WORKERS																										

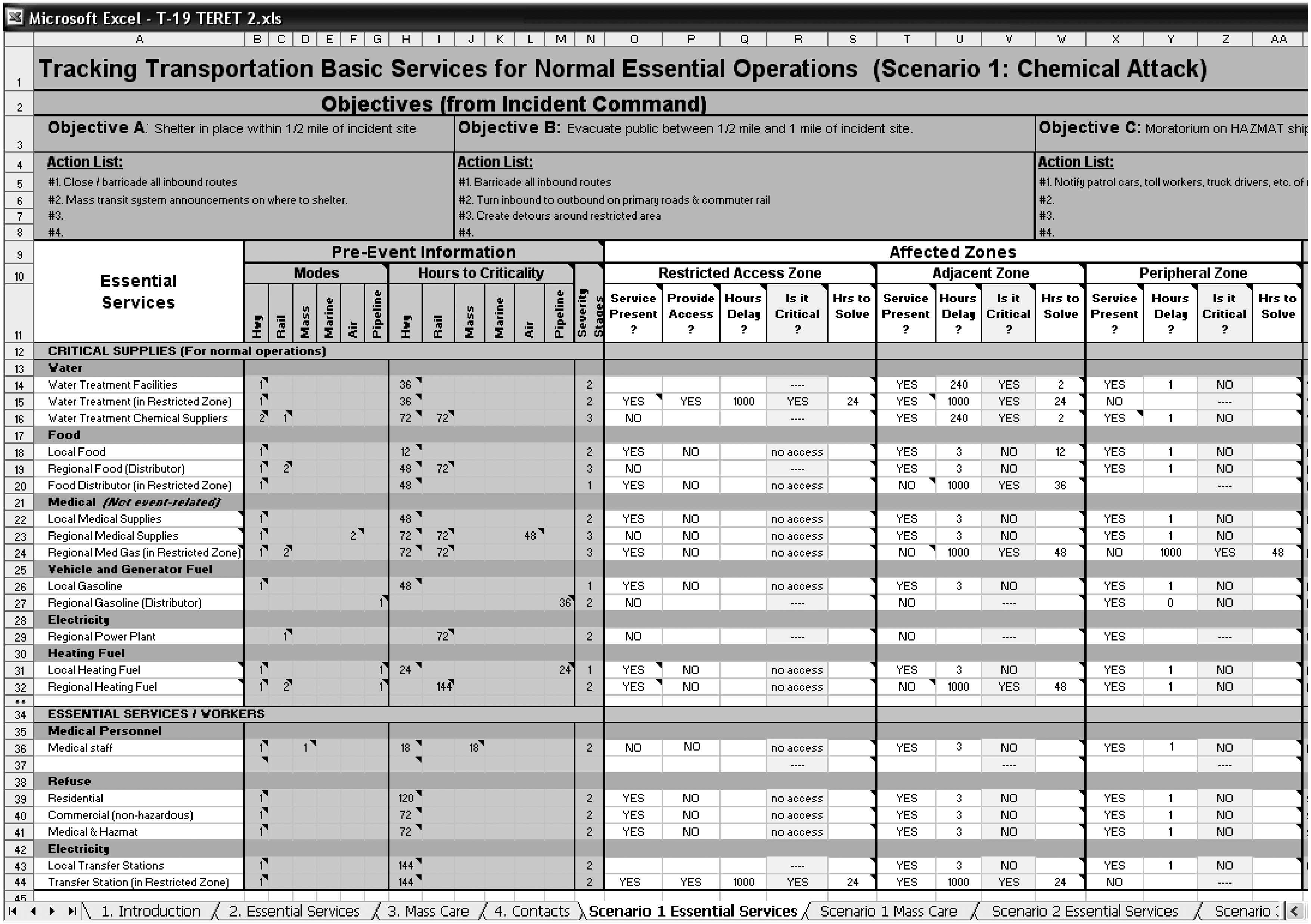
Some water treatment facilities in this zone receive supplies from the chemical supplier in the adjacent zone.

This provider is on the border of the current restricted zone. We need to make plans in the event that this site is in the restricted zone after more detailed contaminant surveys.

This provider is likely to remain in the restricted zone after more detailed contaminant surveys are completed. The severity level is 3 -- we need to give top priority to identifying solutions.

This provider is on the border of the current restricted zone. We need to make plans in the event that this site is in the restricted zone after more detailed contaminant surveys.

Figure 7. View of the Essential Services Worksheet for Scenario 1.



Tracking Transportation Basic Services for Normal Essential Operations (Scenario 1: Chemical Attack)

Objectives (from Incident Command)

Objective A: Shelter in place within 1/2 mile of incident site

Action List:
#1. Close / barricade all inbound routes
#2. Mass transit system announcements on where to shelter.
#3.
#4.

Objective B: Evacuate public between 1/2 mile and 1 mile of incident site.

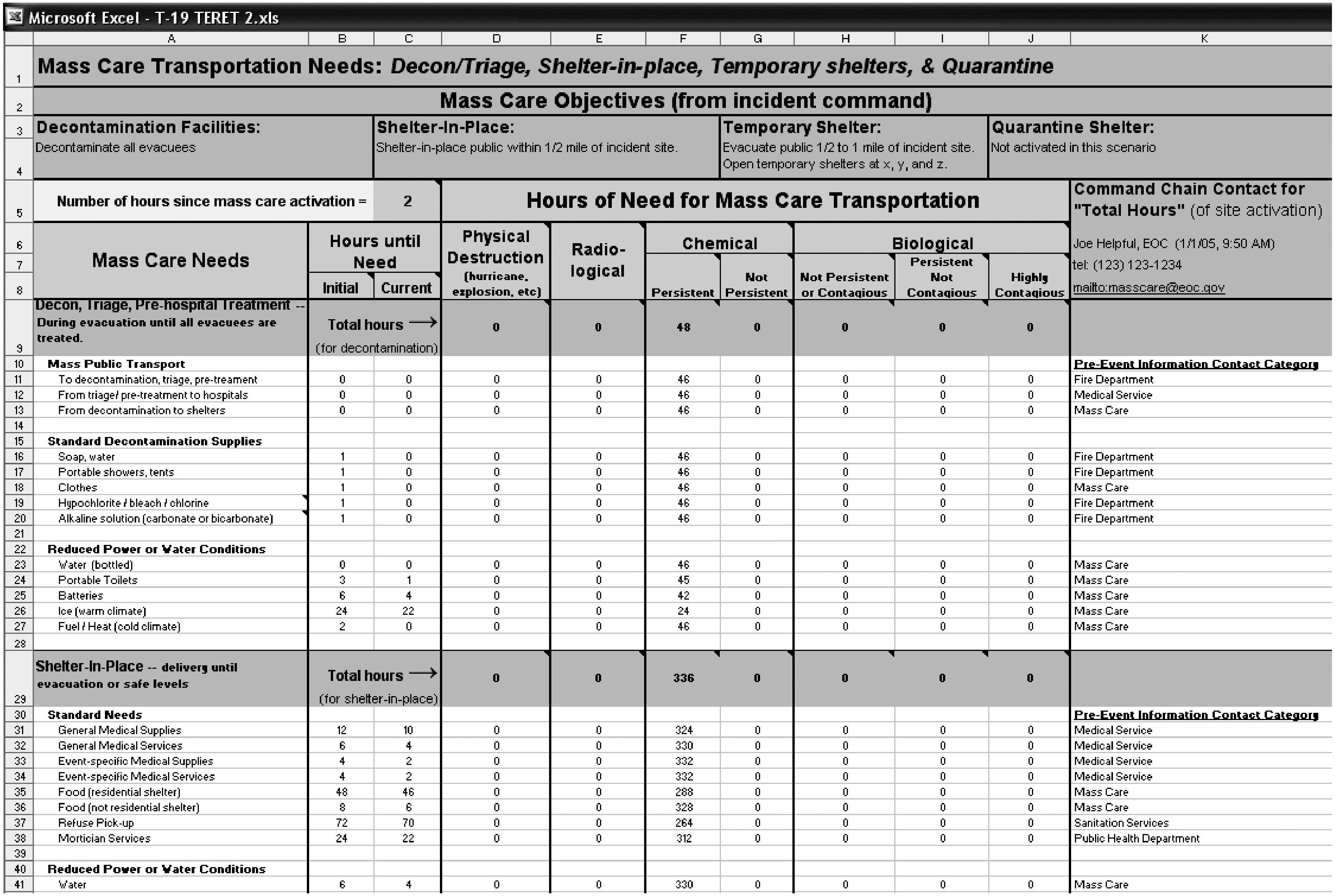
Action List:
#1. Barricade all inbound routes
#2. Turn inbound to outbound on primary roads & commuter rail
#3. Create detours around restricted area
#4.

Objective C: Moratorium on HAZMAT ship

Action List:
#1. Notify patrol cars, toll workers, truck drivers, etc. of
#2.
#3.
#4.

	Pre-Event Information													Affected Zones												
Essential Services	Modes						Hours to Criticality							Restricted Access Zone					Adjacent Zone				Peripheral Zone			
	Hwy	Rail	Mass	Marine	Air	Pipeline	Hwy	Rail	Mass	Marine	Air	Pipeline	Severity Stages	Service Present ?	Provide Access ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve
CRITICAL SUPPLIES (For normal operations)																										
Water																										
Water Treatment Facilities	1						36						2				----		YES	240	YES	2	YES	1	NO	
Water Treatment (in Restricted Zone)	1						36						2	YES	YES	1000	YES	24	YES	1000	YES	24	NO		----	
Water Treatment Chemical Suppliers	2	1					72	72					3	NO			----		YES	240	YES	2	YES	1	NO	
Food																										
Local Food	1						12						2	YES	NO		no access		YES	3	NO	12	YES	1	NO	
Regional Food (Distributor)	1	2					48	72					3	NO			----		YES	3	NO		YES	1	NO	
Food Distributor (in Restricted Zone)	1						48						1	YES	NO		no access		NO	1000	YES	36			----	
Medical ***(Not event-related)***																										
Local Medical Supplies	1						48						2	YES	NO		no access		YES	3	NO		YES	1	NO	
Regional Medical Supplies	1				2		72	72			48		3	NO	NO		no access		YES	3	NO		YES	1	NO	
Regional Med Gas (in Restricted Zone)	1	2					72	72					3	YES	NO		no access		NO	1000	YES	48	NO	1000	YES	48
Vehicle and Generator Fuel																										
Local Gasoline	1						48						1	YES	NO		no access		YES	3	NO		YES	1	NO	
Regional Gasoline (Distributor)						1						36	2	NO			----		NO		----		YES	0	NO	
Electricity																										
Regional Power Plant		1						72					2	NO			----		NO		----		YES		----	
Heating Fuel																										
Local Heating Fuel	1					1	24					24	1	YES	NO		no access		YES	3	NO		YES	1	NO	
Regional Heating Fuel	1	2				1		144					2	YES	NO		no access		NO	1000	YES	48	YES	1	NO	
ESSENTIAL SERVICES / WORKERS																										
Medical Personnel																										
Medical staff	1		1				18		18				2	NO	NO		no access		YES	3	NO		YES	1	NO	
																	----				----				----	
Refuse																										
Residential	1						120						2	YES	NO		no access		YES	3	NO		YES	1	NO	
Commercial (non-hazardous)	1						72						2	YES	NO		no access		YES	3	NO		YES	1	NO	
Medical & Hazmat	1						72						2	YES	NO		no access		YES	3	NO		YES	1	NO	
Electricity																										
Local Transfer Stations	1						144						2				----		YES	3	NO		YES	1	NO	
Transfer Station (in Restricted Zone)	1						144						2	YES	YES	1000	YES	24	YES	1000	YES	24	NO		----	

Figure 8. View of the Mass Care Worksheet for Scenario 1.



	A	B	C	D	E	F	G	H	I	J	K
1	**Mass Care Transportation Needs:** ***Decon/Triage, Shelter-in-place, Temporary shelters, & Quarantine***										
2	**Mass Care Objectives (from incident command)**										
3	**Decontamination Facilities:**		**Shelter-In-Place:**				**Temporary Shelter:**			**Quarantine Shelter:**	
4	Decontaminate all evacuees		Shelter-in-place public within 1/2 mile of incident site.				Evacuate public 1/2 to 1 mile of incident site. Open temporary shelters at x, y, and z.			Not activated in this scenario	
5	**Number of hours since mass care activation =**		2	**Hours of Need for Mass Care Transportation**							**Command Chain Contact for "Total Hours"** (of site activation)
6	**Mass Care Needs**	**Hours until Need**		**Physical Destruction** (hurricane, explosion, etc)	**Radio-logical**	**Chemical**		**Biological**			Joe Helpful, EOC (1/1/05, 9:50 AM)
7									**Persistent Not Contagious**		tel: (123) 123-1234
8		**Initial**	**Current**			**Persistent**	**Not Persistent**	**Not Persistent or Contagious**		**Highly Contagious**	mailto:masscare@eoc.gov
9	**Decon, Triage, Pre-hospital Treatment** -- **During evacuation until all evacuees are treated.**	**Total hours ⟶** (for decontamination)		**0**	**0**	**48**	**0**	**0**	**0**	**0**	
10	**Mass Public Transport**										**Pre-Event Information Contact Category**
11	To decontamination, triage, pre-treament	0	0	0	0	46	0	0	0	0	Fire Department
12	From triage/ pre-treatment to hospitals	0	0	0	0	46	0	0	0	0	Medical Service
13	From decontamination to shelters	0	0	0	0	46	0	0	0	0	Mass Care
14											
15	**Standard Decontamination Supplies**										
16	Soap, water	1	0	0	0	46	0	0	0	0	Fire Department
17	Portable showers, tents	1	0	0	0	46	0	0	0	0	Fire Department
18	Clothes	1	0	0	0	46	0	0	0	0	Mass Care
19	Hypochlorite / bleach / chlorine	1	0	0	0	46	0	0	0	0	Fire Department
20	Alkaline solution (carbonate or bicarbonate)	1	0	0	0	46	0	0	0	0	Fire Department
21											
22	**Reduced Power or Water Conditions**										
23	Water (bottled)	0	0	0	0	46	0	0	0	0	Mass Care
24	Portable Toilets	3	1	0	0	45	0	0	0	0	Mass Care
25	Batteries	6	4	0	0	42	0	0	0	0	Mass Care
26	Ice (warm climate)	24	22	0	0	24	0	0	0	0	Mass Care
27	Fuel / Heat (cold climate)	2	0	0	0	46	0	0	0	0	Mass Care
28											
29	**Shelter-In-Place** -- **delivery until evacuation or safe levels**	**Total hours ⟶** (for shelter-in-place)		**0**	**0**	**336**	**0**	**0**	**0**	**0**	
30	**Standard Needs**										**Pre-Event Information Contact Category**
31	General Medical Supplies	12	10	0	0	324	0	0	0	0	Medical Service
32	General Medical Services	6	4	0	0	330	0	0	0	0	Medical Service
33	Event-specific Medical Supplies	4	2	0	0	332	0	0	0	0	Medical Service
34	Event-specific Medical Services	4	2	0	0	332	0	0	0	0	Medical Service
35	Food (residential shelter)	48	46	0	0	288	0	0	0	0	Mass Care
36	Food (not residential shelter)	8	6	0	0	328	0	0	0	0	Mass Care
37	Refuse Pick-up	72	70	0	0	264	0	0	0	0	Sanitation Services
38	Mortician Services	24	22	0	0	312	0	0	0	0	Public Health Department
39											
40	**Reduced Power or Water Conditions**										
41	Water	6	4	0	0	330	0	0	0	0	Mass Care

4.2 Scenario 2: Biological Attack (Contagious Virus)

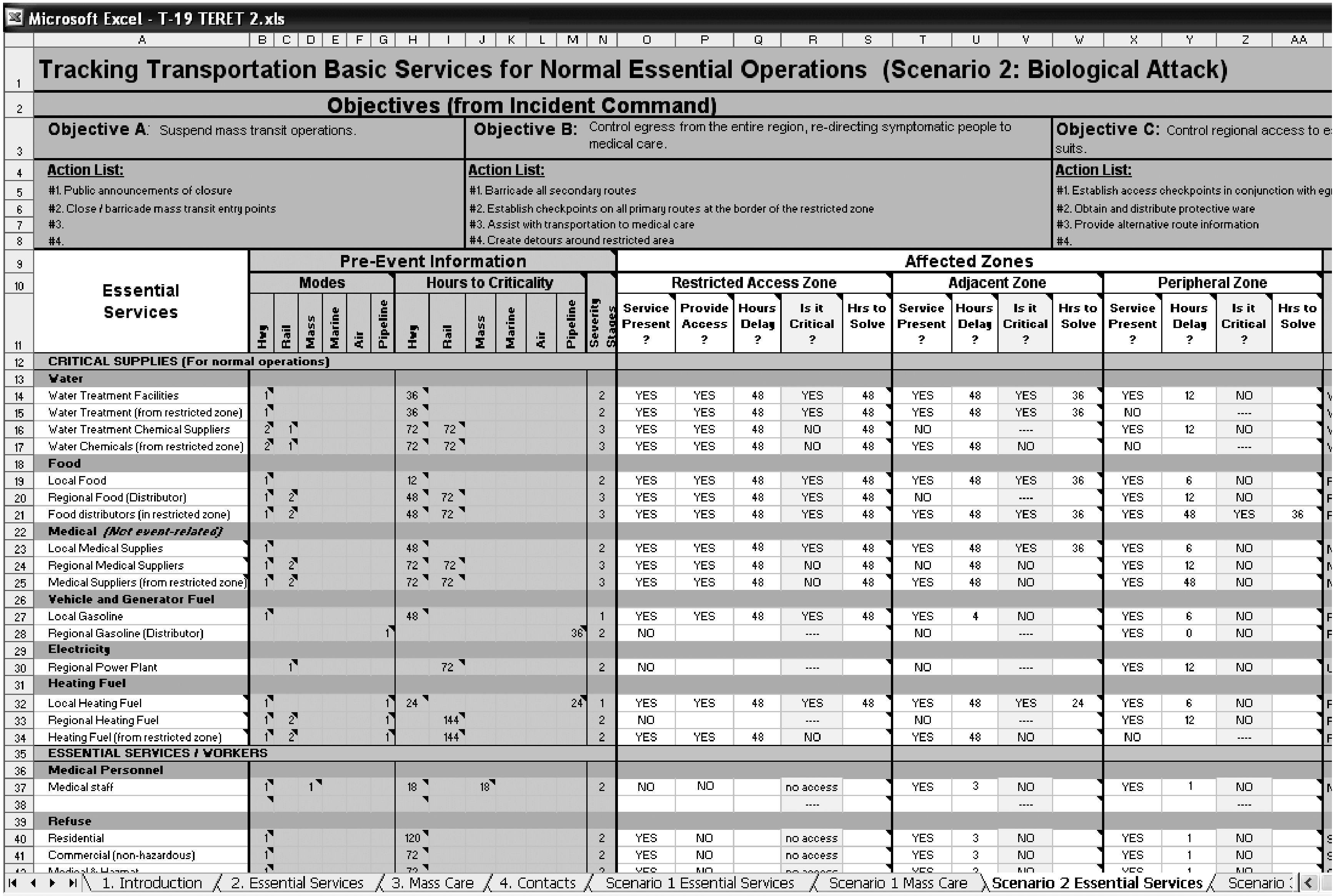
During flu season, the medical facilities in Freedonia record an abrupt onset of flu-like symptoms including fever, headache, muscle aches, joint pain, and sore throat. Samples are sent to the CDC, but firm viral identification will take 5 to 7 days. In the meantime, symptoms progress to vomiting, diarrhea, stomach pain, and on the third day of illness, hemorrhaging is seen as tiny red dots in the skin. This later symptom, in particular, allows presumptive identification of a hemorrhagic fever virus and recognition of a biological attack. The DHS elevates the national threat advisory level to orange. Timelines obtained from patients enable identification of likely release sites as the HVAC systems of Freedonia's City Hall, Convention Center, and International Airport, from which travelers and convention-goers dispersed throughout the country prior to attack recognition. The originally released agent has degraded beyond recognition at the presumed sites, thus the attack sites cannot be confirmed, and there are concerns regarding the possibility of other release sites, particularly within the mass transit system.

Public communication campaigns are initiated to identify initial victims who may not have sought medical care or have delayed symptoms, and to identify secondary victims infected from originally exposed persons. Freedonia’s mass transit system is closed due to concerns of additional releases and vigilante violence in the self-policing of riders in which persons with any unhealthy signs are barred from entry. Hospitals are flooded with the worried-well. Parents withdraw children from school, which are soon closed. Worker absenteeism in Freedonia drastically increases as many people voluntarily evacuate. Truckers refuse to make deliveries to Freedonia. Production at regional facilities within Freedonia drops drastically due to reduced number of workers, and soon thereafter, reduced supplies. The CDC finally confirms the Marburg hemorrhagic fever virus, which can be transferred from person to person with direct or close contact and may cause 25 to 70% fatalities. Treatment is limited to supportive care including blood transfusions, IV fluids, ventilators, and dialysis and regional supplies for these treatments quickly run short as deliveries are not made. Voluntary quarantine/observation centers are established in many of the schools and churches of Freedonia, as well as nationwide for people with flu-like symptoms. Vigilante policing promotes a rapid increase in the voluntary quarantined within the Freedonia region. Checkpoints for egress from the Freedonia Metropolitan Area are established for directing obviously symptomatic people to medical care and obtaining contact and destination information from evacuees. These control points also control access to essential workers and deliveries, and provide bio-level protection suits for those required to enter the region.

The TERET Essential Services worksheet shown in **Figure 9**, below, has been filled in for this hypothetical scenario. **Rows 3 to 8 contain** the objectives from Incident Command, and brief lists of actions taken to meet these objectives. The restricted zone becomes the entire Freedonia Metropolitan Area. Suspension of mass transit affects commuting of essential workers, but does not create a critical condition (shown in **Row 35**). However, delayed supplies received from other regions (due to access checkpoints, dispersal of protective ware, etc.), lead the user to estimate a 48 hour delay in all deliveries within this region (**Column O**). As indicated in **Column R**, these delays suggest the potential for criticalities within the restricted zone in local water treatment supplies, vehicle and generator fuels, and heating fuel. Additional criticalities are indicated for both local and regional food and medical supplies. Because the user was unable to implement solutions that would reduce these delays, the command chain contacts are notified, and may use severity level information in **Column N** to help prioritize address of these potential criticalities.

The user added rows to distinguish supplies that move from the restricted zone to the outlying zones. These supplies include treated water, water treatment chemicals, food, medical, and heating fuel supplies. Delivery of the supplies from the restricted zone is expected to be delayed 48 hours due to the installed checkpoints, as indicated in **Column U**. In this scenario, adjacent zone delays can be reduced by obtaining supplies from other regions with which previous agreements have already been made. Delays in the peripheral zone are due to the increase in the DHS threat advisory level, but in this scenario, none of these delays are expected to cause critical conditions.

Figure 9. View of the Essential Services Worksheet for Scenario 2.



Tracking Transportation Basic Services for Normal Essential Operations (Scenario 2: Biological Attack)

Objectives (from Incident Command)

Objective A: Suspend mass transit operations.

Action List:

#1. Public announcements of closure
#2. Close / barricade mass transit entry points
#3.
#4.

Objective B: Control egress from the entire region, re-directing symptomatic people to medical care.

Action List:

#1. Barricade all secondary routes
#2. Establish checkpoints on all primary routes at the border of the restricted zone
#3. Assist with transportation to medical care
#4. Create detours around restricted area

Objective C: Control regional access to e suits.

Action List:

#1. Establish access checkpoints in conjunction with eg
#2. Obtain and distribute protective ware
#3. Provide alternative route information
#4.

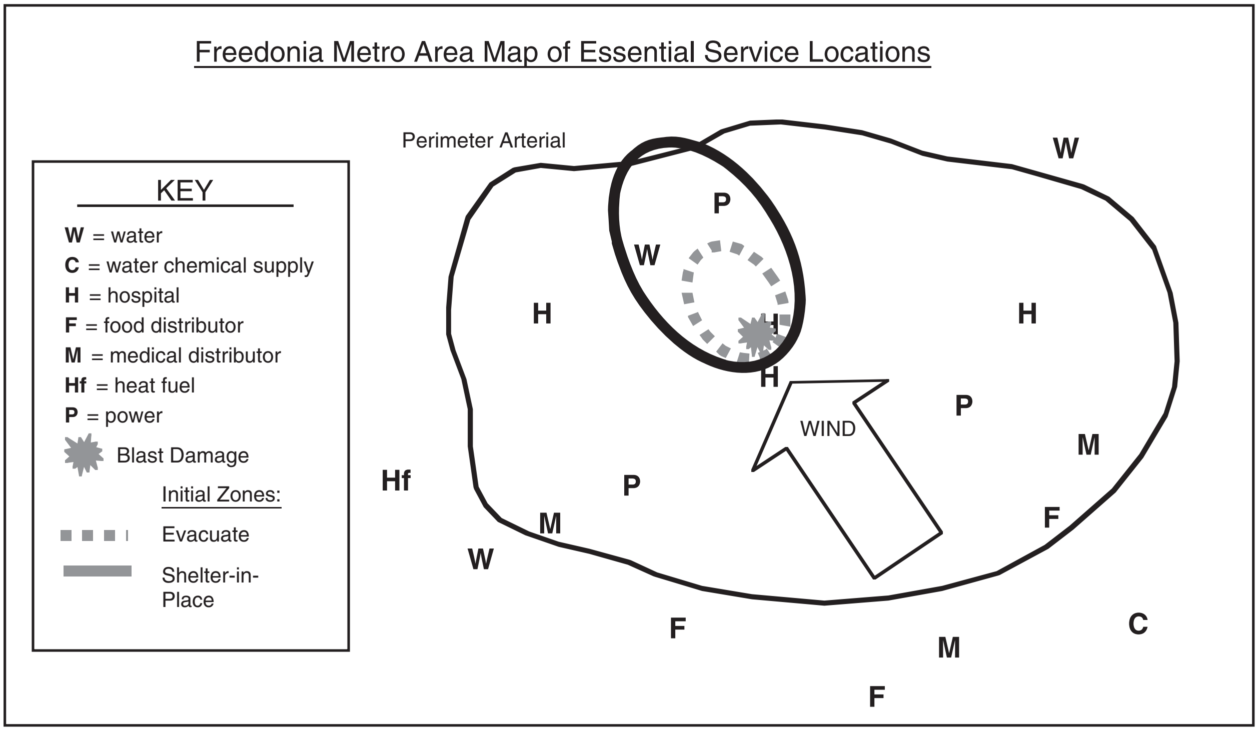
9	Essential Services	Pre-Event Information													Affected Zones												
10		Modes						Hours to Criticality							Restricted Access Zone					Adjacent Zone				Peripheral Zone			
11		Hwy	Rail	Mass	Marine	Air	Pipeline	Hwy	Rail	Mass	Marine	Air	Pipeline	Severity Stages	Service Present ?	Provide Access ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve
12	**CRITICAL SUPPLIES (For normal operations)**																										
13	**Water**																										
14	Water Treatment Facilities	1						36						2	YES	YES	48	YES	48	YES	48	YES	36	YES	12	NO	
15	Water Treatment (from restricted zone)	1						36						2	YES	YES	48	YES	48	YES	48	YES	36	NO		----	
16	Water Treatment Chemical Suppliers	2	1					72	72					3	YES	YES	48	NO	48	NO		----		YES	12	NO	
17	Water Chemicals (from restricted zone)	2	1					72	72					3	YES	YES	48	NO	48	YES	48	NO		NO		----	
18	**Food**																										
19	Local Food	1						12						2	YES	YES	48	YES	48	YES	48	YES	36	YES	6	NO	
20	Regional Food (Distributor)	1	2					48	72					3	YES	YES	48	YES	48	NO		----		YES	12	NO	
21	Food distributors (in restricted zone)	1	2					48	72					3	YES	YES	48	YES	48	YES	48	YES	36	YES	48	YES	36
22	**Medical** ***(Not event-related)***																										
23	Local Medical Supplies	1						48						2	YES	YES	48	YES	48	YES	48	YES	36	YES	6	NO	
24	Regional Medical Suppliers	1	2					72	72					3	YES	YES	48	NO	48	NO	48	NO		YES	12	NO	
25	Medical Suppliers (from restricted zone)	1	2					72	72					3	YES	YES	48	NO	48	YES	48	NO		YES	48	NO	
26	**Vehicle and Generator Fuel**																										
27	Local Gasoline	1						48						1	YES	YES	48	YES	48	YES	4	NO		YES	6	NO	
28	Regional Gasoline (Distributor)						1						36	2	NO			----		NO		----		YES	0	NO	
29	**Electricity**																										
30	Regional Power Plant		1						72					2	NO			----		NO		----		YES	12	NO	
31	**Heating Fuel**																										
32	Local Heating Fuel	1					1	24					24	1	YES	YES	48	YES	48	YES	48	YES	24	YES	6	NO	
33	Regional Heating Fuel	1	2				1		144					2	NO			----		NO		----		YES	12	NO	
34	Heating Fuel (from restricted zone)	1	2				1		144					2	YES	YES	48	NO		YES	48	NO		NO		----	
35	**ESSENTIAL SERVICES / WORKERS**																										
36	**Medical Personnel**																										
37	Medical staff	1		1				18		18				2	NO	NO		no access		YES	3	NO		YES	1	NO	
38																		----				----				----	
39	**Refuse**																										
40	Residential	1						120						2	YES	NO		no access		YES	3	NO		YES	1	NO	
41	Commercial (non-hazardous)	1						72						2	YES	NO		no access		YES	3	NO		YES	1	NO	

4.3 Scenario 3: Radiological Attack (Dirty Bomb)

A truck bomb explodes in Freedonia's city center. First-responders rush to aid blast victims. After 15 minutes, Cesium-137 (half-life = 33 years) is detected by first-responders with portable radiation detectors. Initial readings of radioactivity and a moderate, steady wind (4 to 8 mph) from the southeast leads the Incident Commander to order evacuations from the detonation site to ½ mile downwind, and shelter-in-place from ½ to 1 mile downwind, as illustrated in **Figure 10**.

Decontamination and triage sites are established for all evacuees, who are not permitted to leave until they are cleared by the FBI. Department of Homeland Security (DHS) elevates the national threat advisory level to orange. A sewage treatment plant in the initial shelter-in-place zone is found to have insignificant levels of contamination, but a more detailed radiological survey shows that buildings and topography have caused wind eddies and vortices that create highly variable and unpredictable levels of contamination, and that some buildings in the shelter-in-place zone have significant contamination, creating multiple patches of hazardous areas (i.e., restricted zones). Hospitals are flooded with the worried-well. It is determined that most of the Cesium-137 particles were larger than 10 micron (i.e., not inhalable), and they have largely bound to concrete and other masonry. A long and costly clean-up is projected (i.e., 2 to 3 years) for most buildings and roads in the evacuation zone and some buildings in the shelter-in-place zone. No symptoms of acute radiation sickness are found, however the area where this may have occurred had fatalities due to the explosion. The lifetime cancer risk is increased proportionate to the doses of radiation received.

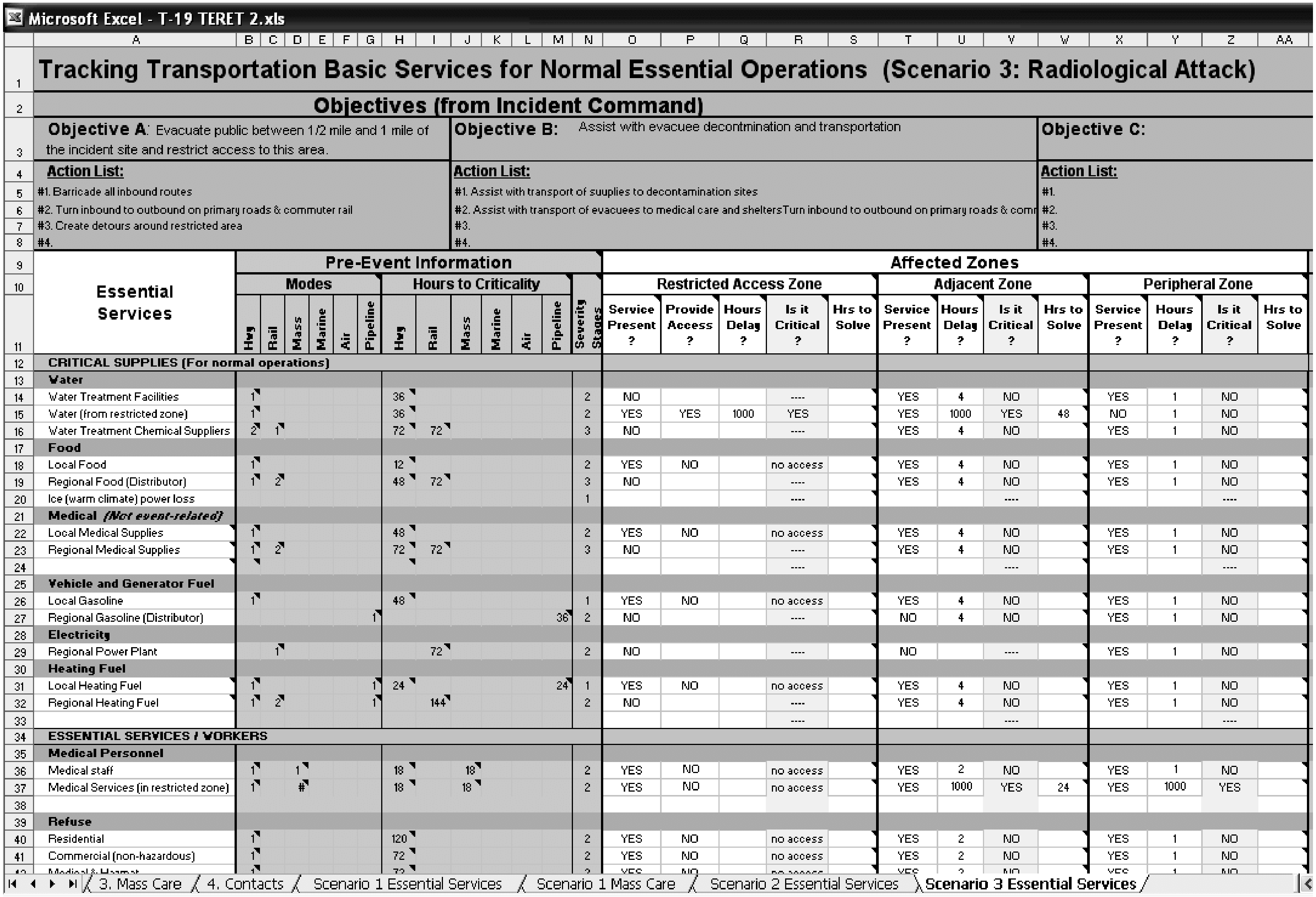
Figure 10. Scenario #3 -- Schematic Presentation of a Radiological Attack Area



The TERET Essential Services worksheet shown in **Figure 11**, below, has been filled in for this hypothetical scenario. **Rows 3 through 8** show the objectives from incident command and the actions taken to meet these objectives. The user added new rows for the supplies and services in the restricted zone that are provided to the outlying areas. These include water treatment, and electricity from a local transfer station (the incident comment has allowed access to maintain these services), and medical services from a regional hospital is in the restricted zone. For hours delay in service from the restricted zone, the user enters a large number (i.e., 1000) in **Columns Q, U, and Y**. Obtaining waivers and procedures for vehicle decontamination after deliveries to the restricted zone is estimated to take 48 hours for continued water and power service (**Column S**).

For the lost regional medical services provided by the hospital in the restricted zone, public announcement are made to direct patients to other facilities. General delays in the adjacent zone due to detours and associated congestion are estimated to be 4 hours (**Column U**), which is not projected to cause any criticalities. The only services to the peripheral zone that originate in the restricted zone are those of the closed hospital. As in the adjacent zone, public announcement are made to direct patients to other providers.

Figure 11. View of the Essential Services Worksheet for Scenario 3.



Tracking Transportation Basic Services for Normal Essential Operations (Scenario 3: Radiological Attack)

Objectives (from Incident Command)

Objective A: Evacuate public between 1/2 mile and 1 mile of the incident site and restrict access to this area.

Action List:
#1. Barricade all inbound routes
#2. Turn inbound to outbound on primary roads & commuter rail
#3. Create detours around restricted area
#4.

Objective B: Assist with evacuee decontmination and transportation

Action List:
#1. Assist with transport of suuplies to decontamination sites
#2. Assist with transport of evacuees to medical care and sheltersTurn inbound to outbound on primary roads & comn
#3.
#4.

Objective C:

Action List:
#1.
#2.
#3.
#4.

Essential Services	Pre-Event Information													Affected Zones												
	Modes						Hours to Criticality						Severity Stages	Restricted Access Zone					Adjacent Zone				Peripheral Zone			
	Hwy	Rail	Mass	Marine	Air	Pipeline	Hwy	Rail	Mass	Marine	Air	Pipeline		Service Present ?	Provide Access ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve	Service Present ?	Hours Delay ?	Is it Critical ?	Hrs to Solve
CRITICAL SUPPLIES (For normal operations)																										
Water																										
Water Treatment Facilities	1						36						2	NO			----		YES	4	NO		YES	1	NO	
Water (from restricted zone)	1						36						2	YES	YES	1000	YES		YES	1000	YES	48	NO	1	NO	
Water Treatment Chemical Suppliers	2	1					72	72					3	NO			----		YES	4	NO		YES	1	NO	
Food																										
Local Food	1						12						2	YES	NO		no access		YES	4	NO		YES	1	NO	
Regional Food (Distributor)	1	2					48	72					3	NO			----		YES	4	NO		YES	1	NO	
Ice (warm climate) power loss													1				----				----				----	
Medical *(Not event-related)*																										
Local Medical Supplies	1						48						2	YES	NO		no access		YES	4	NO		YES	1	NO	
Regional Medical Supplies	1	2					72	72					3	NO			----		YES	4	NO		YES	1	NO	
																	----				----				----	
Vehicle and Generator Fuel																										
Local Gasoline	1						48						1	YES	NO		no access		YES	4	NO		YES	1	NO	
Regional Gasoline (Distributor)						1						36	2	NO			----		NO	4	NO		YES	1	NO	
Electricity																										
Regional Power Plant		1						72					2	NO			----		NO		----		YES	1	NO	
Heating Fuel																										
Local Heating Fuel	1					1	24					24	1	YES	NO		no access		YES	4	NO		YES	1	NO	
Regional Heating Fuel	1	2				1		144					2	NO			----		YES	4	NO		YES	1	NO	
																	----				----				----	
ESSENTIAL SERVICES / WORKERS																										
Medical Personnel																										
Medical staff	1		1				18		18				2	YES	NO		no access		YES	2	NO		YES	1	NO	
Medical Services (in restricted zone)	1		#				18		18				2	YES	NO		no access		YES	1000	YES	24	YES	1000	YES	
Refuse																										
Residential	1						120						2	YES	NO		no access		YES	2	NO		YES	1	NO	
Commercial (non-hazardous)	1						72						2	YES	NO		no access		YES	2	NO		YES	1	NO	

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation