Chapter 8

Transportation and ______

Introduction

Previous chapters examined public health-related transportation issues that have received a great deal of attention in the literature and that have been subject to research on the underlying causal phenomena. This chapter examines some topics that have not received as much attention, at least not concerning the potential roles for transportation in mitigating or avoiding public health impacts.

The reason the chapter is entitled "Transportation and _____" is that transportation is viewed in this book as enabling many other outcomes, many of which have clear public health impacts and consequences. To some extent, this chapter represents all other possible linkages between transportation and public health. In this chapter, we examine two major categories of public health concerns relating to transportation—those that relate to what is carried by transportation systems (people, goods, and pathogens) and those that relate to direct and indirect consequences when transportation systems are disrupted. In the first category, we will examine three major topics, transportation's role in (1) transmitting infectious diseases (e.g., enabling pandemics), (2) the transfer of invasive species in the natural environment, and (3) transporting hazardous materials. The two topics examined in the second category are climate change and disaster response. In each of these cases, the transportation system is either a contributor to public health consequences (a carrier of infected persons or animals) and/or a contributor to mitigating the negative public health outcomes (e.g., evacuation or disaster recovery routes).

Public health and what transportation systems convey

In what is now an iconic visual used by transportation and security officials to illustrate the role of transportation systems in national and community emergencies, the shutdown of the US national airspace after the terrorist attacks of 9/11 showed how over a very short time period airplanes in the United States and those destined to the United States were diverted to the nearest airports. National security officials did not know how many other airplanes might have been hijacked by terrorists and targeted at major cities. A protocol

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had been in place for many years that allowed the Administrator of the Federal Aviation Administration (FAA) to order the closure of US airspace in the event of a national emergency. On the ground, the Washington D.C. metro system was shut down after the attack on the Pentagon because security officials did not know if there were other terrorists in the city trying to reach targets or trying to escape. Similarly, after the Boston Marathon bombing, the City of Boston and regional transportation authorities closed the freeway system, regional transit, airport, and intercity rail services to not allow the bombers to escape.

These examples show the important role of transportation systems in conveying people and goods (or possibly harmful materials), and how they can in themselves become part of a strategy to harm people or disrupt communities/economies. The exact nature of the public health threat will vary by how transportation systems are used and what they carry. The airplanes in the 9/11 attacks were clearly part of the weapon delivery system; a hazardous materials spill is more an issue of what a train, truck, barge, or ship is carrying.

Transmittal of infectious disease

Table 8.1 was prepared by the King County government (Seattle—Washington State) to give a sense of what the range of a serous influenza epidemic might mean to the United States and to King County. The estimates were based on historical records from past influenza epidemics.

TABLE 8.1 Estimated number of episodes of illness, health-care utilization, and deaths associated with moderate and severe pandemic influenza scenarios for the US population and King County, Washington, 2013.

	Moderate (like 1958/68)		Severe (like 1918)	
Characteristic	**United States**	**King County**	**United States**	**King County**
Illness	90 million	540,000	90 million	540,000
Outpatient care	45 million	270,000	45 million	270,000
Hospitalization	865,000	5190	9,900,000	59,400
Intensive care unit (ICU) care	128,750	773	1,485,000	8,910
Mechanical ventilation	64,875	389	742,500	4,455
Deaths	209,000	1,254	1,903,000	11,418

Source: King County (2013).

One must be cautious in basing future forecasts on these estimates because these historical events did not have available many of the medical treatments we have today (e.g., antiviral therapy, ventilators and intensive care units). In addition, the social, economic, and environmental conditions today are very different than those of the past. Modern medicines, population monitoring for early onslaught of illness, and a medical establishment prepared to handle emergencies might suggest that the epidemic/pandemic outcomes of the past (where tens of millions died) would not likely occur today. However, at the same time, the more extensive and interconnected global air system (permitting more rapid and dispersed transmittal of communicable diseases) and the ability of small groups of individuals (terrorists) to manufacture and deliver biological weapons are much greater today. These considerations would suggest that such epidemic/pandemic outcomes might be even more serious than those of the past.

Due to their very nature, transportation systems allow the physical movement of, and enable contact among, many different people. In the course of many types of trips, there are many surfaces that have been touched by other people. Medical science has known for some time that sneezing, coughing, talking, and even breathing can carry pathogens that expose others nearby. Pathogens are also easily transferred from one person to another by the touching of infected surfaces that are used by many different people over the course of a day (e.g., ticket machines, turnstiles, door handles, poles or straps in subway cars that provide support against vehicle acceleration, and toilet facilities). To the extent that pathogens or toxins are transmitted to others on a journey (either through physical contact or airborne), it is the transportation system that permits this to happen. Some research indicates, for example, that very small droplets from a sneeze can in fact travel around 200 feet (Kopman, 2014). On airplanes, a study conducted by the US National Academies found that for people seated within a seat or two to the side of someone who is infected, or within one row forward or backward, the chances of catching a contagious virus were about 80%; outside of that immediate radius; however, the risk was much lower—only about 3%.

In medical terms, the route or mode of transmission refers to the mechanism by which a communicable disease is spread. For example, modes of transmission include direct transmission, which includes respiratory droplet and direct contact; indirect transmission, for example, airborne or indirect contact via a fomite (contaminated surface); and via a vector, which is the means of transferring a pathogen, for example, malaria/zika via mosquitoes and Lyme disease via ticks.

The more efficient the mode of transmission (and this is what transportation officials constantly strive for in the transportation sector) combined with the virulence of a pathogen, the faster the potential transmission of disease.

In a global economy connected by supply chains in the freight sector and tied together with global air travel to most major regions of the world, the potential for rapid and widespread transmission of infectious diseases and other harmful elements can be very high. Indeed, a major concern of national health and security officials is that such transmission could occur before authorities even know that it is happening (the incubation time for many communicable diseases is 1−4 days, much longer than it takes for someone to travel around the world).

Historical evidence of transportation as a mode of disease transmission

Evidence of rapid (in relative terms when looking historically) transmission of disease comes from the historical records of pandemics and the spread of infectious disease that have occurred throughout the world. The eradication of entire Native American civilizations from smallpox brought to the western hemisphere by Christopher Columbus and subsequent European expeditions well illustrate the potential world-spanning threat from the transmittal of infectious diseases via transportation.

The bubonic plague (Black Death) which swept across Africa, Asia, and Europe in the 14th century spread along the major shipping and communications lanes of the time, primarily sea lanes. The conventional rationale for the Black Death was that rats carrying infected fleas traveled in ships bringing with them the plague, starting in harbor cities or in major centers of commerce and then spreading as the rats moved inland. Such an explanation is now questioned given the examination of plague-caused death patterns and the rapidity with which it spread (which does not conform with how fast rats could propagate throughout Europe). Sea transportation is still viewed as a major vehicle in the plague's initial spread, but a leading hypothesis is that it was the human, land-based contact that spread the disease so quickly after being introduced in port cities (Tatem et al., 2006). Historians estimate that worldwide about 50 million people died in the initial plague; in Europe, plague-caused deaths represented between 25% and 60% of the population. An estimated 200 million people died over the three major plague outbreaks from the 14th to 17th centuries.

Rodriquez et al. (2017) report that there have been 10 major influenza pandemics over the past 300 years, with the 1918 Spanish Flu causing an estimated 30% of the world's population to get sick and resulting in the estimated deaths of between 50 and 100 million people (an estimated 40 million in one year alone). It resulted in an almost 10-year drop in the calculated average life expectancy of the global population (Palese, 2004). In the United States, over one-third of the population was affected and 500,000 people died. The virus spread around the world due to many reasons, such as the widespread dislocation of large populations due to World War I. However, many explanations focus on the predominant use of crowded intercity and international modes of travel (that is, rail and ocean liners). It is not surprising to note that some of the most severe outbreaks of influenza centered on shipyards and train stations. In Sweden, major outbreaks or cases were reported in large workplaces such as factories, telegraph and telephone stations, and the tram and railway stations (Holmberg, 2017).

As ever more modern transportation technology produced faster speeds, transportation became an even greater enabler of a pandemic (Wilson, 1995). Saunders-Hastings and Krewski (2016), who examined pandemics since the late 1500s, noted that the state of transportation technology was a likely contributor to the time it took for a disease to spread.

> *In the winter of 1889, an influenza pandemic emerged in Russia, spreading by rail and sea across Europe and North America. With an estimated case fatality rate in the range of 0.1%–0.28%, the outbreak killed about one million people globally. This pandemic spread at a faster rate than previous ones and may provide the first indication of the accelerated spread of emergent diseases as a result of progress in transportation technology.*

With respect to cholera, Tatem et al. (2006) note the importance of transportation in cholera outbreaks, in many cases caused by the movement of military transport.

> *Cholera first started as an epidemic outbreak in 1817 in India, but soon started spreading in part due to British ship and troop movements carrying the infection north and east to China, Japan and Indonesia. The disease also spread along trade routes to the west as far as southern Russia. Each successive pandemic increased in extent and severity, reflecting the expanding reach of the global transport system and increased movements of people, particularly on religious pilgrimages. The 1830s saw Russian troops, English ships, Irish immigrants and Canadian exploration carry the cholera bacterium to the Baltic, England, Ireland, Canada, USA and Mexico.*

More recently, the severe acute respiratory syndrome (SARS) in the early 2000s and the Swine Flu epidemics in 2009 quickly spread because of air travel and in some cases passenger ocean liners. Browne and Beck (2016) noted that air transportation is one of the major means of accelerating and amplifying influenza propagation, occurring aboard the planes as well as at airports.

Regional/local transit

Transportation systems can play a role in spreading communicable disease within urban areas as well, although most likely not as prominent a mode of transmission as other factors (such as community spaces, schools, and areas of employment that allow for direct person-to-person transmission). A simulation of a potential influenza outbreak in New York City based on calibration data from the 1957–58 influenza pandemics and from NYC travel surveys estimated that only 4% of the spread of influenza would occur on the subway (Cooley et al., 2011). However, simulations in Sweden found that banning journeys of more than 50 kms (31 miles) would drastically reduce the speed and geographical spread of influenza outbreaks, even when compliance with the ban was not total. The 50 kms is a typical range for commuter rail services in most major metropolitan areas (Camitz and Liljjeros, 2006).

For surface transportation modes, such as public transit and intercity rail, dealing with an outbreak of a communicable disease or a pandemic could create significant challenges to the transportation agency. Not only is there the potential for the transmission of dangerous microbes in crowded conditions, but the agency employees themselves might succumb to illness or otherwise be unable to report for work, creating a serious constraint on providing service. The same could be true for any major disruption due to earthquake or other regional disasters.

The US National Academies of Sciences, Engineering, and Medicine (2014) produced a "*Guide for Public Transportation Pandemic Planning and Response*" that identified the differences between local disasters that result in service and system disruptions, and more global and national pandemics.

The report identified such differences as:

- Workers could possibly be absent for a short time in local disruptions, whereas they might be absent for extended periods in pandemics
- Disruptions due to extreme weather or terrorist attacks will likely result in infrastructure damage, whereas pandemics do not
- Dealing with the injured from a local disaster could likely be handled by the community medical services whereas pandemics might need massive medical intervention from outside the community

With respect to transit as a means of transmitting communicable diseases, one of the few systematic examinations of the how this could occur was a study supported by the European Union in 2014 called, Prevention and Management of High Threat Pathogen Incidents in Transport Hubs (PANDHUB) (Kulmala, 2016; Enstone and Van-Tam. 2018). The research identified what it called potential transport hot spots for pandemics, defined as "points or sites within a traffic hub environment where the risk of microbial transmission is at least periodically increased due to favorable conditions or human behavior." The possible mechanisms for transmission were: (1) direct and indirect contact and (2) airborne or droplet transmission. These hot spots would likely vary by type of pathogen or microbe and the environmental conditions within which they thrive.

A study by Ikonen et al. (2018), which sampled different locations in an airport, showed the potential hot spots for different types of viruses.

Nucleic acid of at least one respiratory virus was detected in 9 out of 90 (10%) surface samples, including: a plastic toy dog in the children's playground (2/3 swabs, 67%); hand-carried luggage trays at the security check area (4/8%, 50%); the buttons of the payment terminal at the pharmacy (1/2%, 50%); the handrails of stairs (1/7%, 14%); and the passenger side desk and divider glass at a passport control point (1/3%, 33%). Among the 10 respiratory virus findings at various sites, the viruses identified were: rhinovirus (4/10%, 40%, from surfaces); coronavirus (3/10%, 30%, from surfaces); adenovirus (2/10%, 20%, 1 air sample, 1 surface sample); influenza A (1/10%, 10%, surface sample).

Some of the different types of hot spots are shown in Table 8.2.

Of some interest for the transmission of microbes transmitted by indirect contact, the research cited a study that observed people on a metro system touching their faces an average of 3.6 times per hour and common objects an average of 3.3 times per hour (Alonzo et al., 2013). By their behavior, passengers readily provide the means of transferring microbes from a surface to the skin and to mucous membranes in the nasal passage.

What to do about it

Public health and transportation officials agree that being prepared for possible infectious diseases and having strategies, plans, and protocols in place for dealing with such threats at the first sign of infection is an important first step.

TABLE 8.2 Hot spots for transit systems.

Microbe or pathogen	Example	Specifics
Microbes transmitted by indirect contact	Touch screens of self-service automats; security control boxes for carry-on luggage transfer; waiting halls and lavatories and passport control self-service automats	Viruses and bacteria survive for longer on nonporous, water-resistant surfaces Temperature and relative humidity have the greatest effects regarding survival on surfaces
Microbes transmitted by airborne or droplet routes	Traffic hub areas with a high volume and density of passengers, such as station platforms or gates and arrival halls; baggage claim halls; and border control, security control, and custom inspection points	Passenger density and the time or speed of passenger flow between the different hub types will affect both the intensity and the duration of exposure, particularly for droplet transmission

Source: (Kulmala,2016).

This step will vary by level and responsibility of government (see Chapter 3). For example, some of the key observations/conclusions from the first US influenza pandemic plan included the following (Homeland Security Council, 2006).

Federal Government Response to a Pandemic

The goals of the Federal Government response to a pandemic are to (1) stop, slow, or otherwise limit the spread of a pandemic to the United States; (2) limit the domestic spread of a pandemic, and mitigate disease, suffering and death; and (3) sustain infrastructure and mitigate impact to the economy and the functioning of society.

Homeland Security Council. 2006. National Strategy for Pandemic Influenza

- "The center of gravity of the pandemic response will be in communities. The distributed nature of a pandemic, as well as the sheer burden of disease across the nation over a period of months or longer, means that the federal government's support will be limited.
- The federal government will bear primary responsibility for certain critical functions, including (1) support of containment efforts overseas, and limiting arrivals at ports of entry; (2) guidance on protective measures; (3) modifications to the law and regulations to facilitate the national pandemic response; (4) modifications to monetary policy to mitigate the economic impact of a pandemic on communities and the nation; (5) procurement and distribution of vaccine and antiviral medications; and (6) acceleration of research and development of vaccines and therapies during the outbreak.
- The Secretary of Homeland Security is responsible for coordinating federal operations and resources, establishing reporting requirements, and conducting ongoing communications with federal, state, local, and tribal governments, the private sector, and nongovernmental organizations (NGOs).
- The Secretary of Health and Human Services will lead federal health and medical response efforts and will be the principal federal spokesperson for public health issues.
- Measures at the borders might provide an opportunity to slow the spread of a pandemic to and within the United States but are unlikely to prevent it. Moreover, the sheer volume of traffic and the difficulty of developing screening protocols to detect an influenza-like illness pose significant challenges.
- Measures to limit domestic travel may delay the spread of disease. These restrictions could include a range of options, such as reductions in non-

essential travel and, as a last resort, mandatory restrictions …. Communities, states, the private sector, and the federal government will need to carefully weigh the costs and benefits of transportation measures when developing their response plans, including the effectiveness of an action in slowing the spread of a pandemic, its social and economic consequences, and its operational feasibility.

- In order to ensure that international arrivals undergo proper screening protocols and are subject to isolation and quarantine if appropriate, the number of airports accepting international flights will be limited early in a pandemic.
- Managing air passengers who might be infected with an influenza virus having pandemic potential includes isolation of ill persons, quarantine of all non-ill travelers (and crew), and targeted treatment and prophylaxis with antiviral medications.
- The risk of influenza transmission by cargo is low (inanimate ship-borne cargo poses low risk, and routine surfaces are easily decontaminated).
- State, local, tribal, and private sector entities should assess the systemic effects on freight delivery such as supply chain impact, just-in-time delivery, warehousing, and logistics They should develop contingency plans in the event of loss of critical services such as the delivery of essential commodities (e.g., chlorine for water purification, gasoline, food, and medical supplies).
- The federal government recommends that governmental entities and private sector organizations assume that up to 40% of their staff may be absent for periods of about 2 weeks at the height of a pandemic wave, with lower levels of staff absent for a few weeks on either side of the peak.
- Due to stresses placed upon the health-care system and other critical functions, civil disturbances and breakdowns in public order may occur. Likewise, emergency call centers may be overwhelmed with calls for assistance, including requests to transport influenza victims. Local law enforcement agencies may be called upon to enforce movement restrictions or quarantines thereby diverting resources from traditional law enforcement duties. To add to these challenges, law enforcement and emergency response agencies can also expect to have their uniform and support ranks reduced significantly as a result of the pandemic. Private sector entities responsible for securing critical infrastructure will face similar challenges."

For those interested in pandemic strategies for transportation agencies, the National Influenza Pandemic Plan included separate plans for maritime

(DHS, 2008a), rail (DHS, 2008b), transit (DHS, 2008c), aviation (DHS, 2008d), and highway (DHS, 2008e) transportation.

Table 8.3 shows some of the strategies that a transit agency could use to prevent the spread of disease.

TABLE 8.3 Proposed transit measures to prevent the spread of disease.

Phase of Influenza Outbreak	Possible Transit Strategies

Interpandemic Phase—periods between pandemics	• Support emergency risk management capacity development.
	• Develop and maintain continuity of operations plans and protocols that address the unique consequences of a pandemic, including
	  ◦ Absenteeism
	  ◦ Line of succession for the agency
	  ◦ Identification of mission essential services and priorities
	  ◦ Procedures for the reassignment of employees
	  ◦ Redundancy of mission critical communication and information systems
	• Coordinate pandemic response strategies with other agencies in the region to account for the mobility of the population in spreading the disease.
	• Training and technical support to make sure vulnerable populations are able to sustain and access critical services.
	• Identify staff who can be cross-trained to perform emergency response functions.
	• Identify functions that could be temporarily is continued or performed via telecommuting for several weeks.
	• Make sure agency's call center knows how to forward relevant calls to health and medical triage centers.

Alert Phase—influenza caused by a new subtype has been identified in humans. Local area is affected or has extensive travel/trade links with affected areas	• Reassess and recalibrate response plans in light of actual epidemiological features as seen elsewhere and in early stages in impacted area, including case fatality rate and differential impacts on subgroups of the population. • Promote and disseminate pandemic influenza educational messages to the staff. • Identify with local health providers the need for staff to use personal protective equipment such as respirators and surgical masks. • Local surveillance system, coupled with state, national and international surveillance efforts and laboratory testing, serves as an early warning system for potential pandemics. • Begin information campaign to influence public behavior toward basic infection control measures (hand washing, using alcohol hand gel, respiratory etiquette, staying home when sick, and avoiding unnecessary contact with other persons during a pandemic).

TABLE 8.3 Proposed transit measures to prevent the spread of disease.—cont'd

Phase of Influenza Outbreak	Possible Transit Strategies
Pandemic Phase—global spread of human influenza caused by a new subtype. Local area is affected or has extensive travel/trade links with affected areas	• Social distancing measures such as limiting public gatherings and closing schools, colleges, universities, large child care centers, libraries, houses of worship, stadiums, and recreational facilities are intended to decrease opportunities for close contact among persons in the community, thereby decreasing the potential for influenza transmission among people and possibly slowing the spread of a pandemic. • Possibly recommend that people use public transportation only for essential travel or use alternative means of transportation if available. • Disinfect public accessed areas and appurtenances.

Source: (King County, 2013).

Summary

Much has changed since the worldwide pandemics and plagues of past centuries. Historical accounts of the spread of these infectious diseases show the importance of factors such as households (and families), schools, military training camps, city density, and transportation flows. The relative importance of these factors has changed profoundly over time, as have public health interventions, medical care technologies, and nutrition (Holmberg, 2017). However, given continued innovations in transportation and logistics technologies, it seems likely that global transportation systems will continue to become more efficient and reliable. Thus, transportation systems will continue to be an important potential vector for the transmission of communicable diseases (note, this statement does not even consider the use of biological agents in a terrorist attack against transportation systems of which smallpox and anthrax are considered to be the greatest threat).

It seems clear in the literature and in governmental contingency plans that the burden in handling epidemics/pandemics will rest with local public health/medical providers. The transportation component at this level of response could well be making sure the personnel and supplies necessary to be transported into containment zones are available and not hindered due to illness among drivers or pilots.

As noted by Haggett (2000), the transportation contribution to the control of epidemics and pandemics will likely be characterized by the following:

1. "Pandemic control will rely less and less on conventional spatial barriers as the global transport network continues to expand,

2. The speed of modern transportation means prompt surveillance and rapid reporting now play a critical role in preventing the spatial spread of a disease,
3. Mathematical models will become central in identifying aberrant behavior in disease trends, and
4. The high cost of surveillance makes sampling design and the development of cost-effective monitoring and testing approaches vital to effective epidemic early warning systems."

It seems, however, that controlling the dispersion of communicable diseases could still require the isolation of those contaminated, which in turn will likely mean curtailing in some fashion the transportation systems that serve as a vector in disease transmission. This is especially true for the aviation system (note the federal pandemic strategy of allowing international flights to land at only a few, well-prepared airports). If such a strategy is necessary, it will not only cause a massive dislocation of segments of the population who now find themselves stranded in different parts of the country but could well result in large-scale economic costs to global, national, state, and local economies (Meyer and Brown, 2019).

Over the long term, climate change could very well be one of the most influential enablers of newly introduced diseases and vectors that are transported to new environments (CDC and APHA, undated). According to the Fourth US National Climate Change Assessment, "climate change is expected to alter the geographic range, seasonal distribution, and abundance of disease vectors, exposing more people in North America to ticks that carry Lyme disease or other bacterial and viral agents, and to mosquitoes that transmit West Nile, chikungunya, dengue, and Zika viruses. Changing weather patterns interact with other factors, including how pathogens adapt and change, changing ecosystems and land use, demographics, human behavior, and the status of public health infrastructure and management" (U.S. Global Change Research Program, 2018a). More will be said about this later.

The "ride-alongs" in transportation

Transportation systems carry more than just people. Historical accounts from the early use of ships traversing different parts of the globe described how certain types of species (rodents and insects, primarily) were transported as well (Hulme, 2009). The introduction of some of these species has had devastating effects on local ecologies and, in some cases, has created serious public health issues (e.g., introduction of disease-carrying mosquitos) (National Invasive Species Council, 2016). An illustration of the former is where new species have interfered with the recovery or contributed to the decline of 42% of the federally-listed threatened and endangered native species (Kurth, 2017). Other examples include:

- The brown-tail moth as a defoliator of a variety of deciduous trees and shrubs can cause dermatitis and respiratory problems when people come in contact with larval hairs.
- Fires are propagated by flammable invasive plants or by dead trees killed by fungus or boring insects.
- Planting of Australian Melaleuca, Asian cogongrass, and Brazilian pepper along roadsides in Florida became costly hazards due to increased fires along roadways.
- Invasive species such as birds, rodents, and insects (e.g., mosquitoes, fleas, and lice) can serve as vectors of human disease (Dix et al., 2009).

Another common term used for these "ride-alongs" is invasive species. The National Wildlife Federation defines an invasive species as:

> *Any kind of living organism—an amphibian (like the cane toad), plant, insect, fish, fungus, bacteria, or even an organism's seeds or eggs—that is not native to an ecosystem and causes harm. They can harm the environment, the economy, or even human health. Species that grow and reproduce quickly, and spread aggressively, with potential to cause harm, are given the label 'invasive'*
> (National Wildlife Federation, undated (a)).

The US government simply defines an invasive species as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (DOA, undated).

Some of the encroachment of an invasive species into a new ecology is enabled by transportation systems. However, changing climatic conditions, in some cases, have been an additional enabler in allowing species to migrate to parts of the country that in previous decades were inhospitable to that species. Some of these species often become the dominant species in the new ecology (see following discussion of climate change). As noted by Crowl et al. (2009): "Land use and climate change interact with human transportation networks to facilitate the spread of invasive species, vectors, and pathogens from local to continental scales." In addition, many of the invasive species that are causing the most environmental damage are those that were brought to the United States to control another pest species or as "pets" (e.g., the Burmese python which is endangering small mammals, endangered birds, and even alligators in the Everglades, Florida).

The following paragraphs will only focus on the transfer of invasive species due to transportation or via trade enabled by transportation (e.g., of the invasive forest insects and pathogens arriving in the United States over the past 150 years or so, an estimated 70% are thought to have arrived on imported live plants (Epanchin-Niell, 2014). A global database on invasive species listed 255 invasive species that used transportation either as a contaminant or as a "stowaway" for arriving in a new ecology (Invasive Species Specialists Group, 2008). And a research group in the State of Texas in 2014 estimated that more than 800 aquatic and terrestrial species had landed in Texas as of that year and predicted that the trend will continue with the expansion of the Panama Canal encouraging an increased use of Texas ports (Texas Invasive Species Institute, 2014).

Invasive species and mitigation strategies

Some examples of invasive species that were brought to the United States via some form of transportation include:

1. Zebra mussel: Brought in ballast water or attached to the outsides of ships. Because they grow so fast, large populations of zebra mussels filtering water can severely impact native plankton, which reduces food for fish (Earthrangers, 2014).
2. Earthworms: The first earthworms in Minnesota probably arrived with soils and plants brought from Europe when ships using rocks and soil as ballast dumped the soil on shore as they adjusted the ballast weight of the ship. They also were most likely included with imported European plants. The earthworms are causing major damage to hardwood forests in Minnesota (Minnesota Department of Natural Resources, 2019).
3. Asian long-horned beetle: Often encased in wooden packaging materials and trees, the larvae of Asian longhorn beetles eat soft sappy bark, which makes it hard for nutrients to reach other parts of a tree. As they grow, the larvae burrow into the middle of the tree leaving large tunnels as they move, making the tree physically weaker. Many trees do not survive once they are infested with Asian longhorn beetles (Earthrangers, 2014).
4. Asian tiger mosquito: The Asian tiger mosquito entered the United States in shipments of used tires from northern Asia in the mid-1980s. It is a potential vector of encephalitis, dengue (all four serotypes), yellow fever, and dog heartworm. West Nile virus has been detected in this species in the eastern United States (Center for Invasive Species Research, 2016).
5. Northern Pacific seastars: Also brought in ballast water, Northern Pacific seastars have a voracious appetite, eating almost anything they can find. They are believed to be the major reason for the decline of several species of fish (Earthrangers, 2014).

One of the major forms of the species "invasion" into the United States is via ocean-going ships. For example, the National Wildlife Federation (NWF) estimates that more than 185 aquatic invasive species have entered the Great Lakes, and that ocean-going shipping is the No. 1 source of nonnative aquatic species (a new non-native species is discovered on average once every 28 weeks) (National Wildlife Federation, undated (b)). Since the St. Lawrence Seaway connecting the Great Lakes to the Atlantic Ocean was opened in 1959, 85 invasive species have been discovered with 54 linked to ballast water discharge (water carried by ships to help them stay balanced while at sea). The US Maritime Administration (MARAD) notes:

> *Invasive species are considered to be one of the greatest threats to marine and coastal biodiversity world-wide. Aquatic invasions can destroy native ecosystems, overwhelm native species, reduce recreational opportunities, and adversely impact sport and commercial fisheries. Although there are many pathways through which these invasions can occur, transportation in ships' ballast water and in underwater hull biofouling are known contributors*
>
> MARAD (2018).

Since 1993, ocean-going ships have been required to replace their ballast water with ocean water before entering the Great Lakes, known as ballast water exchange (however, some species are still able to survive in this new salty ballast water).

The International Maritime Organization (IMO, 2011) has issued guidelines for the control and management of ships' biofouling (the existence of invasive species) to minimize the transfer of invasive aquatic species. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004) and the Convention on Biological Diversity (1992) served as the basis for the guidelines. The Convention requires participating nations to have a ballast water management plan to help avoid disrupting native ecosystems with invasive aquatic species (Wiant, 2017). Two methods can be used to implement such a plan: (1) using a Ballast Water Exchange Standard, which requires ships to exchange a minimum of 95% ballast water volume at least 50 nautical miles from the nearest shore and in waters of 200 m depth or more (helping prevent invasive species spreading in coastal and shallow waters that are one of the most vulnerable to invasive species) and (2) using a Ballast Water Performance Standard, which establishes thresholds for the presence of aquatic organisms in the ballast water. The water quality limits may be achieved through physical and/or chemical treatment methods.

The ballast water strategy is illustrative of one of the strategies adopted by government agencies to minimize the risk of maritime invasive species, that is, to stop their arriving in the first place. The US Forest Service prohibits the importation of species via environmental and public health regulations it considers to be potentially injurious. Once an invasive species is established in the United States, the next strategy is to control and eradicate it with a variety of actions. These include physical removal, introducing natural predators (which as noted earlier can become themselves a problem), affecting the reproduction environment, or ultimately adopting public health strategies for dealing with the diseases or illnesses borne by the species (e.g., protecting vulnerable populations against mosquito-borne disease outbreaks).

Summary

The transport of animals, insects, molds/fungi or plants that constitute an "attack" on a native ecology is a serious issue and one that has become even more important as global connectivity has increased. The physical transportation of uninvited species along trade routes has resulted in dramatic and significant impacts on native species. From a public health perspective, the invasive species concern is perhaps not as significant as that represented by infectious diseases being carried by passengers. But with changing climatic conditions, newly introduced diseases following transportation vectors could well represent an increasingly important public health issue. Although steps have been taken by government agencies to try and control the risks associated with invasive species, it seems that the trend toward more (and perhaps more deadly) species being introduced into native ecologies will continue.

Transportation and hazardous materials

Each day in 2016 in the United States, the US freight system carried on average 48.3 million tons of goods worth $49.6 billion or about 54.7 tons of freight carried annually for every man, woman, and child in the country (BTS, 2019). In the vast majority of cases, this freight arrives at its destination without incident, and when one looks at the national statistics, the safety record for those moving the freight is very good. However, when accidents or incidents do occur, the aftermath can have serious public health consequences because of what is carried by the trains, trucks, barges, or ships. The 2013 rail catastrophe in Lac-Mégantic, Quebec, for example, resulted in 47 deaths and great property destruction when a train carrying petroleum crashed and exploded. In other cases, when hazardous materials are released as the result of a crash, evacuations of nearby communities often occur as a precaution against serious health consequences. The following sections will examine the transportation and public health challenges associated with the movement of hazardous materials.

Definition of hazardous materials

Depending on the materials being used or transported, government agencies define hazardous materials in different ways (although they often cross-reference one another). For example, the Occupational Safety and Health Administration (OSHA), which is focused primarily on the release of hazardous materials at worksites and at hazardous waste sites, defines a hazardous material as:

> *Any biological agent and other disease-causing agent which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any person, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations in such persons or their offspring;*
>
> *Health hazard means a chemical or a pathogen where acute or chronic health effects may occur in exposed employees. It also includes stress due to temperature extremes. The term health hazard includes chemicals that are classified in accordance with the Hazard Communication Standard as posing one of the following hazardous effects: Acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); aspiration toxicity or simple asphyxiant.*

Department of Labor (undated).

The USDOT defines a hazardous material as:

> *Any item or chemical which, when being transported or moved in commerce, is a risk to public safety or the environment, and is regulated as such under its Pipeline and Hazardous Materials Safety Administration regulations (49 CFR 100—199), which includes the Hazardous Materials Regulations (49 CFR 171—180). In addition, hazardous materials in transport are regulated by the International Maritime Dangerous Goods Code; Dangerous Goods Regulations of the International Air Transport Association; Technical Instructions of the International Civil Aviation Organization; and U.S. Air Force Joint Manual, Preparing Hazardous Materials for Military Air Shipments.*

(Institute of Hazardous Materials and Management, 2018).

The US Environmental Protection Agency (EPA) expands the public health concern to beyond simply human health,

> *Impacts (of hazardous materials) on the environment can be just as devastating: killing organisms in a lake or river, destroying animals and plants in a contaminated area, causing major reproductive complications in animals, or otherwise limit the ability of an ecosystem to survive. Certain hazardous substances also have the potential to explode or cause a fire, threatening both animals and human populations.*

(USEPA, 2017).

Other US agencies that have definitions of hazardous materials include the US Department of Energy (DOE), US Department of Homeland Security (DHS), and the Nuclear Regulatory Commission (NRC). For purposes of this chapter, we will use a general definition offered by the Institute of Hazardous Materials and Management (IHMM, 2018),

> *A hazardous material is any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors.*

Also, for purposes of this chapter, we will focus on the guidance, contexts, and recommended actions as offered by the USDOT and other transportation agencies. For labeling purposes (and for identification on vehicles and in the paperwork that accompanies shipments), the USDOT uses the following classes of hazardous materials:

Class 1: Explosives
Class 2: Gases
Class 3: Flammable liquid
Class 4: Flammable solid, spontaneously combustible, and dangerous when wet
Class 5: Oxidizer, organic peroxide
Class 6: Poison (toxic), position inhalation hazard, infectious substance
Class 7: Radioactive
Class 8: Corrosive
Class 9: Miscellaneous hazardous material (Chisolm, 2018)

Legislative authority

The US government has passed many laws and promulgated many more regulations pertaining to the handling of hazardous materials and how the response to hazardous materials spills should occur. The Hazardous Materials Transportation Act of 1975 (HMTA), and its subsequent amendments, is the most important foundational law for transporting hazardous materials. It empowers the Secretary of Transportation to designate as hazardous material any "particular quantity or form" of a material that "may pose an unreasonable risk to health and safety or property." Subsequent regulations from the respective modal administrations focused on procedures and/or policies, designation of hazardous materials, requirements for packaging and handling such materials, and operational rules when transporting them over the transportation network. In implementing the act, the USDOT named over 3000 materials that fit the definition of a hazardous material and thus subject to regulation. Thousands of other materials were included in the regulations because they were explosive, flammable, corrosive, infectious, or hazardous in other ways.

Even with the HMTA of 1975, the institutional structure for dealing with hazardous materials was complex, complicated, and confusing. Accordingly, the Hazardous Materials Transportation Uniform Safety Act (HMTUSA) was passed in 1990 to rectify conflicting federal, state, and local regulations. The HMTUSA reinforced the Secretary of Transportation's authority to promulgate regulations for the safe transport of hazardous material in intrastate, interstate, and US-oriented foreign commerce. The law also required uniformity among different state and local highway hazardous materials routing regulations, and in the authorization (and criteria) for the issuance of federal permits to motor carriers of hazardous materials and the transport of radioactive materials.

Within the USDOT, the Pipeline and Hazardous Materials Safety Administration (PHMSA) is the lead agency dealing with hazardous materials transportation. According the PHMSA website, its mission is:

> *To protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. To do this, the agency establishes national policy, sets and enforces standards, educates, and conducts research to prevent incidents. We also prepare the public and first responders to reduce consequences if an incident does occur.*
>
> (PHMSA, 2018)

Importantly, PHMSA is the repository of data on hazardous materials incidents for all modes of transportation.

Most state governments have their own legislation and regulations focused on similar topics. As in other policy areas, federal law preempts state and local governmental requirements that are inconsistent with the law.

Extent of hazardous materials transportation

It is important to place the national statistics on hazardous materials incidents/spills in context. Much of the data reported to PHMSA and other federal agencies relate to spills or other incidents at particular sites (e.g., at an oil distribution center) and that do not require evacuation of nearby communities (PHMSA, 2017). The public health concern is primarily for those affected by a spillage and for those responding to the incident. The following data should thus not be viewed as indicating a rash of hazardous materials spills throughout the United States, but rather as an indication of any type of spill that meets the criteria for reporting to the federal government.

To place the hazardous spills data in context, the latest Bureau of Transportation Statistics (BTS) annual report on the US transportation system notes the following (Note: some dates are for 2016, 2017, or 2018 depending on the original source of data):

- The US freight system carried 17.7 billion tons of goods in 2018 valued at over $18.1 trillion. By 2045, this is expected to reach 25.5 billion tons.

- About one-half of the weight and one-third of the value of this freight is moved less than 100 miles (much of this in metropolitan areas).
- The number of ton-miles (one ton moved one mile, in some sense an exposure measure for the possibility of spills) of freight moved in 2016 was just under 5 trillion ton-miles. The following statistics were for the major transporters of heavy freight, (BTS, 2017)
  - Trucks: 2.02 trillion ton-miles
  - Railroads: 1.59 trillion ton-miles
  - Pipelines: 896.3 billion ton-miles
  - Water (barges): 477.9 billion ton-miles
- Crude/refined oil and hazardous liquid pipelines carried 3.1 billion barrels in 2017; natural gas production in the same year was 27.3 trillion cubic yards of which 34% was carried in pipelines.
- There has been a dramatic increase in the total crude oil moved by rail, from 23.7 million barrels in 2010 to 139.8 million in 2017.

By any measure, the amount of freight/commodity/product moved annually in the United States is impressive. Although there is not an exact measure of how much of this freight is carrying hazardous materials, a 2012 study by the USDOT (the latest that is reported) showed the data indicated in Table 8.4.

As shown in Table 8.4, by far the largest tonnage of hazardous materials carried by value, tonnage, and ton-miles was for flammable liquids. Using ton-miles as a measure of potential exposure of the general population to toxic materials, the next two commodities were corrosive materials and gases.

The number of incidents occurring in 2018 over the entire process of handling hazardous materials (which includes more than just transportation) is shown in Table 8.5 for non-pipeline transportation and Table 8.6 for pipelines. For pipelines, the number of serious incidents declined from 37 in 2005 to 26 in 2017. A serious incident is one resulting in a fatality or requiring an overnight, in-patient hospitalization. The top 10 types of incidents included are shown in Table 8.7.

Those killed or injured from these incidents included:

- Emergency responder (Fire, Police, Emergency Medical Technicians (EMTs) …): 0 hospitalized, 10 nonhospitalized, and 0 deaths
- Transportation employee: 15 hospitalized, 88 nonhospitalized, and 3 deaths
- General public: 0 hospitalized, three nonhospitalized, and 0 deaths

Public health implications of hazardous materials transportation

As noted earlier, the USDOT identified over 3000 materials that could be considered "hazardous" when being transported. Clearly, the public health consequences of these materials will be very different depending on the composition of the particular toxic materials, the method of transmission, the

TABLE 8.4 US hazardous materials shipments by hazard class (2012).

Hazard class and description	Value		Tons		Ton-miles		Average miles per shipment
	(Billion $)	Percent	(Millions $)	Percent	(Billions $)	Percent	
Class 1. Explosives	18	0.8	4	0.2	1	0.3	840
Class 2. Gases	125	5.4	165	6.4	33	10.8	57
Class 3. Flammable liquids	2,017	86.4	2,203	85.4	205	66.5	93
Class 4. Flammable solids	5	0.2	11	0.4	6	1.9	565
Class 5. Oxidizers and organic peroxides	8	0.3	12	0.5	5	1.8	437
Class 6. Toxics (poison)	15	0.7	8	0.3	4	1.2	513
Class 7. Radioactive materials	12	0.5	S	U	0	U	34
Class 8. Corrosive materials	76	3.2	125	4.9	38	12.3	264
Class 9. Miscellaneous dangerous goods	58	2.5	51	2.0	16	5.2	530
Total	2,334	100.0	2,580	100.0	308	100.0	114

KEY: U = data are not available or less than 1 unit of measure or rounds to zero; *S* = data were not published because of high sampling variability or other reasons.
Source: (BTS, 2014)

TABLE 8.5 Hazardous non-pipeline materials incidents, United States, 2018.

Transportation phase	Incidents	Hospitalized	Nonhospitalized	Fatalities	Damages
IN TRANSIT	4838	7	24	3	$48,270,018
Rail	435	1	6	0	$10,931,558
Highway	3732	6	14	3	$37,334,960
Water	3	0	0	0	$2500
Air	668	0	4	0	$1000
IN TRANSIT STORAGE	672	1	6	0	$760,897
Rail	18	0	1	0	$77,695
Highway	381	0	5	0	$643,202
Water	3	0	0	0	$0
Air	270	1	0	0	$40,000
LOADING	3809	0	29	0	$4,425,545
Rail	9	0	0	0	$129,592
Highway	3593	0	27	0	$4,235,854
Water	2	0	0	0	$30,000
Air	205	0	2	0	$30,099
UNLOADING	9571	8	42	0	$18,743,077
Rail	18	1	0	0	$42,157
Highway	9350	7	42	0	$18,696,920
Water	n.a.	n.a.	n.a.	n.a.	n.a.
Air	203	0	0	0	$4000

Source: (PHMSA, 2019).

TABLE 8.6 Top 10 pipeline incidents in the United States by hazard, 2018.

	Number of incidents	Hospitalized	Nonhospitalized	Fatalities
Flammableccombustible liquid	7,016	5	13	3
Corrosive material	5,000	5	55	0
Oxidizer	775	2	11	0
Miscellaneous hazardous material	732	0	3	0
Other regulated material	562	0	4	0
Nonflammable ccompressed gas	355	0	0	0
Flammable gas	343	0	5	0
Poisonous materials	307	2	2	0
Organic pperoxide	161	0	1	0
Flammable solid	84	0	0	0

Source: (PHMSA, 2019).

TABLE 8.7 Health effects of exposure to chemicals.

Body system	Possible health effects
The **respiratory system's** function is to supply oxygen to the body and remove carbon dioxide. It includes nasal passages, pharynx, trachea, bronchi, and lungs.	Asbestosis, lung cancer, chronic bronchitis, fibrosis, emphysema, and decreased oxygen supply in blood.
The **renal system's** function is to rid the body of waste, regulate the amount of body fluids, and regulate the amount of salts in the body. It includes the kidneys, urethra, bladder, and the ureter.	Decreased formation of urine, decreased blood flow to the kidneys, decreased ability to filterblood, prevented urine flow, kidney tissue damage, and kidney cancer.
The **cardiovascular system's** function is to move nutrients, gases, and wastes to and from the body, help stabilize body temperature, and fight diseases and infections by transporting white blood cells to important areas. It includes the heart, blood, arteries, veins, and capillaries.	Heart failure and the inability of blood to carry the necessary oxygen to the body.

Continued

TABLE 8.7 Health effects of exposure to chemicals.—cont'd

Body system	Possible health effects
The **reproductive system's** function is to produce egg and sperm cells, nurture a developing fetus, and produce hormones. For males it includes the testicles, seminal vesicles, prostate gland, and the penis. For females it includes the uterus, bladder, vagina, fallopian tubes, ovaries, and the cervix.	Decreased ability to have a baby, increased baby deaths, increased birth defects, and infertility (the inability to have children).
The **nervous system's** function is to transmit messages from one part of the body to another. It includes the central nervous system (the brain and spinal cord) and the peripheral nervous system.	Inability to move, loss of feeling, confusion, and decreased speech, sight, memory, muscle strength, or coordination.
The **immune system's** function is to protect the body from tumor cells, environmental substances, and invading viruses or bacteria. It includes the lymph system, bone marrow, white blood cells, and the spleen.	Overreaction to environmental substances (allergy), immune system slow down or failure, and autoimmunity (causing the body to attack itself, which makes it more likely to have an overreaction or infection).
The **skin** serves as a barrier to germs and other substances, prevents dehydration, and regulates body temperature.	Skin irritation, rash, redness or discoloration, dermatitis, and health effects related to other systems and organs due to contamination through the skin.
The **hepatic system's** function is to break down food and store nutrients, make proteins which are essential for blood to clot, and purify the body of drugs, contaminants, or chemicals. It includes the liver and its veins.	Liver damage, tumors, accumulation of fat (steatosis), and death of liver cells.

(CDC, undated)

environmental conditions needed for this transmission, and the level of exposure to sensitive populations, to name a few. It is beyond the scope of this book to provide coverage for every possible release of toxic materials. Table 8.7 provides a good overview produced by the Centers for Disease Control (CDC) of the different systems in the body that could be affected by (in this case) chemical toxins (also see (CDC, 2001a) for an extensive listing of potential health effects associated with different toxic exposures).

For larger scale disasters (and certainly for regional disasters such as hurricanes or earthquakes), community- or neighborhood-level evacuations can cause serious emotional and mental stress. The public health community has recognized the immediate and longer term medical needs of those coping with the disruption, loss, and dislocation that accompany such events. Referred to as "behavioral disaster health," it consists of the provision of mental health, substance abuse, and stress management services to disaster survivors and responders.

According to the DHHS, typical symptoms after a disaster include

- Emotional symptoms such as irritability or excessive sadness.
- Cognitive dysfunction such as difficulty making decisions or following directions.
- Physical symptoms such as headache, stomach pain, or difficulty breathing.
- Behavioral reactions such as consuming more alcohol or interpersonal conflict.
- Failure to adhere to needed physical or psychiatric medication needs (DHHS, 2012b).

Special attention might be needed for at-risk individuals found in an affected zone. The 2013 Pandemic and All-Hazards Preparedness Reauthorization Act defined at-risk individuals as "children, older adults, pregnant women, and individuals who may need additional response assistance." The DHHS further defined these populations as including but not limited to "individuals with disabilities, individuals who live in institutional settings, individuals from diverse cultures, individuals who have limited English proficiency or are non-English speaking, individuals who are transportation-disadvantaged, individuals experiencing homelessness, individuals who have chronic medical disorders, and individuals who have pharmacological dependency" (DHHS, 2016).

For those who respond to incidents or disasters, their exposure to possible widespread destruction, injury, death of others, or hazardous materials could result in distress and a need for mental health support as well.

Being prepared

As with any kind of community/public health/transportation system disruption, one of the most effective strategies for minimizing the impacts of a disruption is to be prepared beforehand. This could include establishing the protocols on who will respond, having what responsibilities, using training programs and field exercises to practice the response given different scenarios, and continually incorporating new technologies and medical practices into the emergency response procedures. A collaborative and coordinated approach to such incidents is particularly needed when hazardous materials are present. Such materials could affect not only the health of nearby residents but so too of those who respond. A good understanding of what the hazardous material is along with the possible human health consequences requires close collaboration among the transportation, emergency response, and the public health/medical communities.

The transportation of hazardous materials is accompanied by several safeguards that help those who are responding to an incident. These include distinctive vehicle/car/vessel labeling, cargo information input into a national database for certain types of movements, and travel permits that identify what was being carried. As noted by the CDC,

> *The aim of emergency personnel should be to make a chemical-specific identification while exercising caution to prevent exposure to any chemicals. Identifying the hazardous material and obtaining information on its physical characteristics and toxicity are vital steps to the responder's safety and effective management of the hazardous materials incident. Since each compound has its own unique set of physical and toxicological properties, early and accurate identification of the hazardous material(s) involved allows emergency personnel to initiate appropriate management steps at the scene.*
>
> (CDC, 2001a)

The CDC's Agency for Toxic Substances and Disease Registry developed a three-volume guide for responding to hazardous materials incidents. Volume 1 was "*Emergency Medical Services: A Planning Guide for the Management of Contaminated Patients*"; volume 2 was "*Hospital Emergency Departments: A Planning Guide for the Management of Contaminated Patients*"; and volume 3 was "*Medical Management Guidelines (MMGs) for Acute Chemical Exposures*" (CDC, 2001b). Although dated, these references still offer very useful suggestions on how to handle hazardous materials incidents. Other useful references include those from DOE (undated), Hazardous Materials (HazMat) Incidents — Links and Resources (undated), and the Hazardous Materials Cooperative Research Program of the Transportation Research Board (TRB, 2019).

Most federal agencies, states, cities, and many local communities have developed emergency operations plans that lay out the steps in responding to a hazardous material incident. Although the exact steps to develop such a plan will vary by community, the general steps can be described as follows (the description is generally adopted from the Federal Emergency Management Agency) (FEMA, 2013):

1. Identify participants

   Participants should include members with diverse experience in the execution of the plan. The group's collective expertise should include experience in planning; knowledge of the community; experience with the local response forces; and knowledge of hazardous materials, their effects, and appropriate medical treatments.
2. Analyze risks

   The process should identify the community's potential hazardous materials risks primarily through the use of reports submitted by local industries required by federal law but supplemented by analysis of hazardous materials transport and other potential local hazards identified by community members.

3. Identify special populations and areas of concern

   Areas that are particularly vulnerable to incidents and populations that would require special planning to protect or evacuate in an emergency (such as nursing home residents) should be identified and contingency plans developed.

4. Identify available resources

   Police agencies and fire officials should assess their capabilities to respond to different types of incidents. This should include understanding what resources and help can be anticipated from surrounding communities and state and federal agencies. In addition, the assessment should also include response capabilities of local industry and transporters, specifically those that have the potential to be involved in a hazardous materials incident. Protocols then need to be developed to designate specific responsibilities of all those who will be involved in an incident.

5. Develop the operations plan

   A plan is prepared, reviewed, adopted, and periodically updated by relevant agencies.

6. Test the plan and practice procedures

   Relevant agencies and involved organizations (such as hospitals and large private firms in the area) should conduct exercises (simulations of emergency situations) to determine whether responders are prepared to handle their assigned roles and whether the planned procedures are effective. Ranging in complexity from "tabletop" discussions to the actual deployment of significant resources and personnel (as if in response to an incident), exercises are the best way to find out if the community is ready for a specific type of emergency.

Two major roles for public transportation agencies in the planning for incident response, especially for large-scale disruptions having widespread impacts across multiple economic sectors and markets, is to (1) get the transportation system operating again as soon as possible after an event, as well as supporting other agencies in dealing with public safety and public health issues associated with the aftermath.

The role of local medical and public health providers in a response to a hazardous materials spill will be different from one community to another and will vary by type of hazard. Surprisingly, an example from Washington D.C. suggests that at least for some types of hazards and in at least one region, well-defined roles were not clear (Schulman, 2015). The DHHS in collaboration with the National Association of County and City Health Officials (NACCHO) sought to determine how local health departments (LHDs) could best contribute to a large-scale chemical event response. A focus group of 33 local, state, federal, and nonprofit agency representatives in the National Capital

Region met to discuss possible roles. The result of the focus group was that the participants had very different perspectives on the role of LHDs in a chemical response. Though LHDs have responsibility for protecting human health in all hazards, the role of LHDs was perceived to be limited to disease prevention and control and not really in responding to a hazardous material incident. As noted by Schulman (2015), "the perception of chemical incidents as hazardous material (hazmat) events, and not public health events, may result in LHDs being left out of the loop, even after the incident transitions to a mass casualty or mass fatality event." She also identified the following roles for LHDs.

- "Public health surveillance activities are crucial to determining that an event has happened, as well as the nature of the event. Routine passive surveillance results can be monitored for unusual symptoms associated with chemical exposures.
- LHDs' preexisting community relationships position them to be a trusted source of risk communications. While other responders handle the hazardous materials, LHDs have the ability to calm and inform the populace.
- LHDs provide subject matter expertise to healthcare partners on matters such as the toxicity of chemical agents and sampling and screening approaches. If the agent is unknown, LHDs could use epidemiologic investigation methods to help identify it.
- Other potential roles based on LHD expertise include: (a) coordinating the provision of mental and behavioral health services to affected communities; and (b) providing guidance to ensure the safety and health of on-the-ground responders.
- Public health expertise on the impacts of chemical agents also provides extensive opportunities to support and collaborate with healthcare and environmental health partners.
- LHDs may play a role assessing and monitoring the environmental impact of the agent and the pathways by which it travels. With their knowledge of environmental health impacts, LHDs define exclusionary zones and evacuation areas to ensure public safety, as well as to issue advisories related to drinking water and food safety.
- Once a response reaches the recovery phase, LHDs may be responsible for long-term monitoring of exposed individuals and environmental health impacts, as well as continued risk communication should environmental contamination linger."

An effective and safe response to a hazardous material spill also involves the carriers of the material (Meyer and Brown, 2019). Many businesses have developed plans for what to do in response to an incident that define the responsibilities for each unit in the firm depending on the type of disruption. Many large shippers and carriers also have specially-trained emergency response teams that can assist in the response to a hazardous materials incident. The business plans generally fall under the concept of business continuity plans. The importance of such plans was highlighted by the Great East Japan Earthquake of 2011 where global supply chains were disrupted for months due to the disruption of the critical supply of motor vehicle products centered in the affected area in Japan. One of the outcomes from this experience was that most Japanese firms now have business continuity plans outlining the steps that will be taken for responding to immediate threats associated with such a magnitude of disruption. However, the major focus of business continuity plans is on the business itself and steps that need to be taken to recover service, maintain customer relations, and avoid negative impacts on the market value of the firm. Very few plans devote much attention to the broader picture of how interaction with public agencies, especially for planning ahead of such incidents, should occur.

Summary

Much attention has been given to the challenges and public health risks associated with hazardous materials transport. In part because of the potentially calamitous impacts of a hazardous release (especially in a dense urban area), a wide and diverse range of public agencies, nongovernmental organizations, private companies, public health providers, and emergency responders have been engaged for many years in preparing for such incidents. Over the past several decades, many incidents have provided lessons on what should be done in preparing for and responding to different scenarios. The key message from all of these experiences is that preparing and practicing for any exigency is the best possible way of minimizing the human and environmental impacts of hazardous material spills. The role of public health and medical providers is critical to this response, as is the role of all the other agencies involved with responding to and recovering from the challenges of hazardous material spills.

Public health and disrupted transportation systems

Throughout this book, we have described transportation systems as enabling other activities to occur. The opposite of this also is true—many activities do not occur if transportation systems are disrupted. In the parlance of transportation professionals, the desire is to have a resilient transportation system. Resilience in this sense has two major meanings—the transportation network has redundancy built in to allow other routes to be used (albeit not as conveniently) or the system can recover in a period of time such that the inconvenience is tolerable.

Transportation systems can fail for all sorts of reasons. Natural causes include extreme weather events resulting in storm surges, flooding, or wildfires or manmade events such as labor strikes at transportation terminals (such as ports) or terrorist attacks. In the latter case, terrorist attacks against transportation systems are the number one target of terrorists worldwide, primarily for the visibility it provides to the attack. Transportation systems are also relatively easy to access (Meyer, 2009).

Most transportation agencies have developed protocols for responding to such disruptions. States along the Gulf coast, for example, know what to do when hurricanes threaten, how to preposition equipment and personnel, how to interact with other agencies to restore service as quickly as possible and to assist in community recovery. Clearly, there is a public health component in many types of transportation disruptions as, for example, was discussed in the chapter on traffic safety. In the following sections, two public health/transportation concerns are discussed relating to transportation system disruptions. The first relates to climate change, the long-term consequences to the environment and to infrastructure that was built with very different assumptions of future temperatures, precipitation, and storm intensities. There are serious public health consequences associated with these changes. In some cases, there is a nexus between these public health consequences and transportation.

We should note here that no material is presented in this section that is intended to establish the case for a changing climate. We strongly believe the vast majority of climate scientists who predict vastly different future environmental conditions 50−100 years from now. Those interested in useful background information are referred to the Intergovernmental Panel on Climate Change (IPCC, 2014) and the Fourth US National Climate Assessment (U.S. Global Change Research Program, 2018a,b).

The second topic covered in this section relates to disaster response. To some extent, the concepts relating to disaster response have been covered in the sections on pandemics and hazardous materials spills. However, the material discussed in this section broadens the coverage to what is called the "all-hazards" approach to preparing for large-scale system disruptions. Because this book is focusing on the importance of collaboration among the many different groups and organizations involved with responding to disruptions, we believe more attention is merited.

Climate change: The future will not be an extension of the past

In transportation infrastructure planning, engineers and planners use models to predict the future vehicle and person flows that will likely be using the transportation systems of the future (in order to determine where and how much new transportation capacity will be needed). These models are deemed "behavioral" in that they include variables that reflect how human behavior in making travel decisions will be influenced by changes in such things as trip price, availability of different modes of transport, perceptions of safety, and the like. Even though they are considered "behavioral," most of the models are calibrated on historic travel data; in other words, the relationships among the key variables are assumed to be similar in the future as they have been in the past.

With respect to infrastructure design, engineers use approved manuals and environmental input data that are often based on historic trends and years of practical use. Although there is now movement to modify some of these technical references, many still are based on historic trends (e.g., the intensity-duration-frequency (i-d-f) curves used by many to estimate precipitation and drainage flows are based on historic rainfall data). Fig. 8.1 shows modeled future average global temperatures (in Centigrade) assuming four different scenarios for global greenhouse gas (GHG) emissions (denoted in the figure as Representative Concentration Pathways [RCPs] identified by the Intergovernmental Panel on Climate Change [IPCC]). RCP 8.5 is the worst-case scenario where GHG emissions continue to go up, which many scientists believe to be the most likely scenario; and RCP 2.6 is the best-case scenario where GHG emissions stabilize. The most important observation of this figure is that sometime in the 2030s, the curves diverge. Only one of the four scenarios could be considered as an extension of past trends, and even here the curve shows a faster growth rate than previous years. The future is not going to be like the past.

The same is generally true for other climatic conditions as well. Precipitation patterns are expected to change; predictions of extreme storms (e.g., hurricanes) are not clear, although most seem to agree that whatever the number of storms, their intensity is likely to be much greater than in the past; and with more intense coastal storms comes higher storm surge, especially when this surge occurs on top of sea level rise. All of these future weather

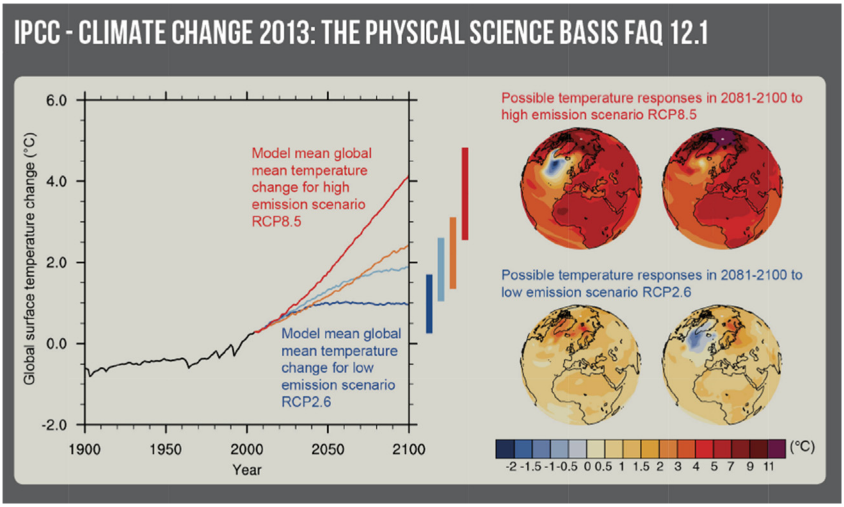

FIGURE 8.1 Predicted global surface temperatures given different greenhouse gas emission scenarios. *Source: Caltrans (2018).*

conditions have serious implications to public health, transportation, and to those concerns where they intersect.

Climate change and public health

A great deal of attention has been given to the potential effects of climate change on public health (see for example, Anderson et al., 2017; Patz, 2004; Patz et al., 2006; Stone et al, 2014; WHO, 2016; Ziska et al, 2016). The Centers for Disease Control (CDC, 2014) and the Fourth US National Climate Assessment (2018) are two useful sources of information. The material found in this section largely draws upon these two sources.

The public health chapter of the *Fourth US National Climate Assessment* made the following key observations:

- The health and well-being of Americans are already affected by climate change, with the adverse health consequences projected to worsen with additional changes in climate.
- Climate change affects human health by altering exposures to heat waves, floods, droughts, and other extreme events; vector-, food- and waterborne infectious diseases; changes in the quality and safety of air, food, and water; and stresses to mental health and well-being.
- People and communities are differentially exposed to hazards and disproportionately affected by climate-related health risks. Populations experiencing greater health risks include children, older adults, low-income communities, and communities of color.
- Proactive adaptation policies and programs reduce the risks and impacts from climate-sensitive health outcomes and from disruptions in healthcare services.
- Additional benefits to health arise from explicitly accounting for climate change risks in infrastructure planning and urban design.
- Reducing greenhouse gas emissions would benefit the health of Americans in the near and long term. By the end of this century, thousands of American lives could be saved, and hundreds of billions of dollars in health-related economic benefits would be gained each year under a pathway of lower greenhouse gas emissions (U.S. Global Change Research Program, 2018b).

Two other ways of conceptualizing the public health consequences of climate change are shown in Figs. 8.2 and 8.3. Fig. 8.2 shows the different public health risks associated with different types of climate change. Several of these linkages could include a transportation component (e.g., traffic injuries due to severe weather; transportation as a vector given new changes in vector ecology; transportation access to healthy food or alternatively disruptions to current food supply chains due to system failures, and the like).

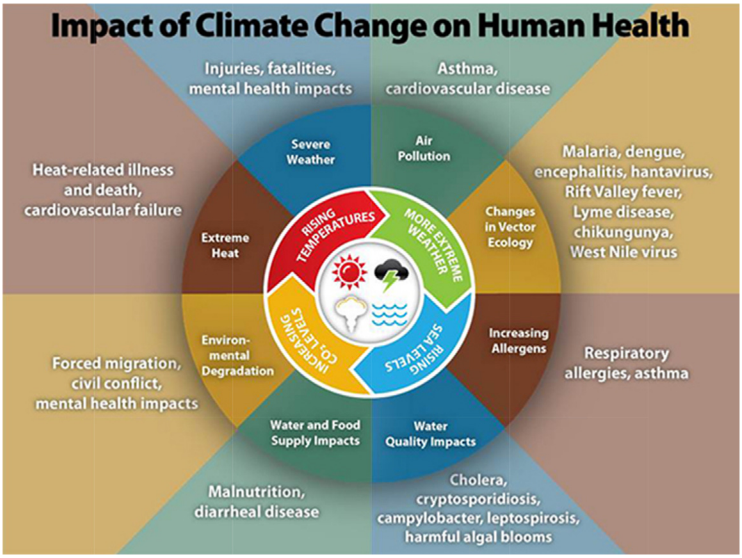

FIGURE 8.2 Public health risks relating to changes in climatic conditions. *Source: CDC (2014).*

Fig. 8.3 illustrates the point made elsewhere in this book that there are many different "drivers" and contexts that contribute ultimately to health outcomes.

In one of the more important papers on the role of public health officials in a climate change future, Frumkin et al. (2008) suggested that there are many such roles in all of the essential services associated with the public health profession. These are shown in Table 8.8. They make the point that one of the key principles in public health—disease or illness prevention—can be applied to climate change-related public health threats. As noted, "primary prevention corresponds to mitigation—efforts to slow, stabilize, or reverse climate change by reducing greenhouse gas emissions. Secondary and tertiary prevention corresponds to adaptation—efforts to anticipate and prepare for the effects of climate change, and thereby to reduce the associated health burden" (Frumkin et al., 2008). The concepts of mitigation and adaptation are found in other fields as well, including transportation. As will be seen later, transportation adaptation includes giving transportation facilities and assets the ability to withstand weather-related risks.

An excellent example of how public health agencies can examine potential climate change risks to public health is found in the California Department of Public Health (CDPH) county-level climate change studies. The study of Imperial County in the southeastern part of the state, which includes the hottest location in the United States (Death Valley), provides an illustration of

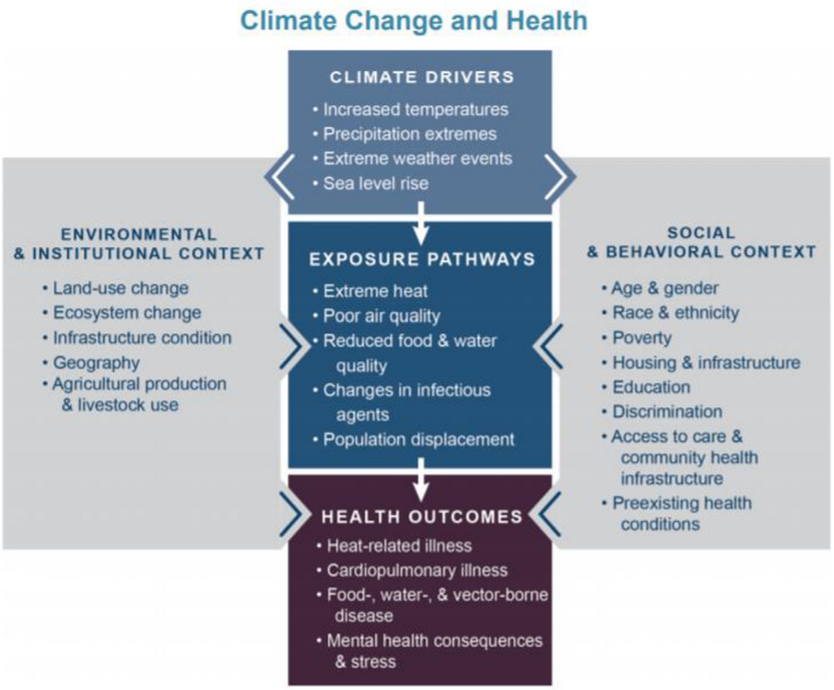

FIGURE 8.3 Potential exposure pathways for climate change effects on human health. *Source: Balbus et al. (2016)*.

TABLE 8.8 The 10 essential services of public health, with climate change examples.

Service	Climate change example
Monitor health status to identify and solve community health problems.	Tracking of diseases and trends related to climate change
Diagnose and investigate health problems and health hazards in the community.	Investigation of infectious water-, food-, and vector-borne disease outbreaks
Inform, educate, and empower people about health issues.	Informing the public and policymakers about health impacts of climate change
Mobilize community partnerships and action to identify and solve health problems.	Public health partnerships with industry, other professional groups, faith community, and others, to craft and implement solutions

TABLE 8.8 The 10 essential services of public health, with climate change examples.—cont'd

Service	Climate change example
Develop policies and plans that support individual and community health efforts.	Municipal heat wave preparedness plans
Enforce laws and regulations that protect health and ensure safety.	(Little role for public health)
Link people to needed personal health services and ensure the provision of health care when otherwise unavailable.	Health-care service provision following disasters
Ensure a competent public and personal healthcare workforce.	Training of health-care providers on the health aspects of climate change
Evaluate effectiveness, accessibility, and quality of personal and population-based health services.	Program assessment of preparedness efforts such as heat wave plans
Research new insights and innovative solutions to health problems.	Research on health effects of climate change, including innovative techniques such as modeling, and research on optimal adaptation strategies

Source: (Frumkin et al, 2008) as adapted from (Public Health Functions Steering Committee, 1994)

what such a study entails (CDPH, 2017). The outline of the report includes the following sections:
What are the climate projections for the Desert Region?
What are the climate projections for Imperial County?

- Projected temperature changes
- Current fire hazard severity zones
- Projected wildfire acreage

Overview of climate change and health impacts

- Extreme weather-related injury, displacement, and mental health
- Health impacts of heat
- Health impacts of drought
- Vector-borne illness and food insecurity
- Sea level rise, mold, and indoor air quality
- Socioeconomic disruption

Which population subgroups are most vulnerable?
What are the health status, health inequities, and population vulnerabilities in Imperial County?

Selected public health strategies and action steps for climate change

Of special note in this list is the emphasis on vulnerable populations. Some observations on such groups included (note: data come from 2010 unless otherwise indicated):

- There were 13,526 children under the age of 5 years and 18,152 adults aged 65 years and older considered among climate-vulnerable groups.
- There were 10,517 people living in nursing homes, dormitories, and other group quarters where institutional authorities would need to provide transportation in the event of emergencies.
- Imperial County had approximately 6,366 outdoor workers whose occupation increased their risk of heat illness.
- Roughly 10 percent of households did not own a vehicle that could be used for evacuation (statewide average was 8%).
- In 2009, approximately 32% of households were estimated to lack air conditioning, a strategy to counter adverse effects of heat (statewide average was 36%).
- In 2005–10, there was an annual average of 135 heat-related emergency room visits and an age-adjusted rate of 78 emergency room visits per 100,000 persons (the statewide age-adjusted rate was 10 emergency room visits per 100,000 persons) (CDPH, 2017).

The study also identified some typical strategies that the county could adopt to be better prepared for future climate change public health risks. Table 8.9 shows a sample of these strategies.

In sum, public health officials are aware of the public health risks associated with a changing climate in part because new climatic conditions largely exacerbate the morbidity and mortality of currently known diseases. In some cases, new diseases show up in regions that had not seen them before because the environment is now more conducive to organisms that heretofore had been unable to survive. As seen in the Imperial County case, much of the attention of the public health community with regard to climate change–related health risks is focused on vulnerable populations, those who will be particularly affected by the new extremes (of temperature, precipitation, winds, etc.) that will become much more common.

Climate change and transportation

Most transportation officials in the United States take the stance that their agencies are well-positioned to respond to any weather-related disruptions to the transportation system and/or that transportation infrastructure is designed with enough buffer in the design to handle any possible stress caused by extreme weather (FHWA, 2016). This ignores the bigger issue of how the transportation system can be made more resilient in the face of a range of future climate change risks, and the even broader question of how climate-safe

TABLE 8.9 Recommended climate change–public health strategies in Imperial County, California, California Department of Public Health.

Strategies	Near-term actions	Long-term term actions
Promote community resilience to climate change to reduce vulnerability	• Promote healthy, built environments • Identify and reduce health vulnerabilities • Improve food security and quality	• Promote food sustainability • Reduce heat islands • Support social and community engagement • Promote increased access to health care
Establish, improve, and maintain mechanisms for robust rapid surveillance of environmental conditions, climate-related illness, vulnerabilities, protective factors and adaptive capacities	• Monitor outcomes (state and local) • Develop existing environmental contaminant biomonitoring • Maintain and upgrade water accessibility information • Improve heat warning systems	• Convert to electronic surveillance systems to improve disease reporting, management, and surveillance
Improve and sustain public health preparedness and emergency response	• CDPH and local health departments should refine existing preparedness plans and conduct exercises	
Work in multisectoral partnerships (local, regional, state, and federal)	• Expand training and education to build collaborative capacity	
Implement policy changes at local, regional, and national levels	• Policy collaboration with stakeholders • Occupational safety standards	• Model policies and training • Public engagement

Source: (CDPH, 2017)

infrastructure should be part of community resilience strategies that serve diverse roles.

As noted earlier, the approach adopted by those transportation officials concerned with climate change and extreme weather is to focus on the adaptation of the transportation system to potential climate change impacts. This certainly includes how one approaches the design of infrastructure, of which many assets by their very nature will likely be still in place by the year 2100 (useful lives of large bridges, for example, are usually over 100 years). But adaptation also affects the entire operation of a typical transportation agency from planning to operations to maintenance. One of the lessons from Hurricane Irene that created havoc with Vermont's transportation system (and with communities throughout the state) was that many of the road collapses occurred at drainage culverts which were clogged with debris (most had not been cleaned out).

An example of how one type of climate stressor could affect the transportation system is provided in Meyer and Cumming (2016) who looked at the potential impacts of extreme heat on transportation systems.

Design

- Instability of materials exposed to high temperatures over longer periods of time can result in increased failures, such as pavement heave or track buckling. Pavement designs in particular are very sensitive to temperature.
- Ground conditions and less water saturation (due to drought conditions) can alter the design factors for foundations and retaining walls such as is occurring with the melting of permafrost in Alaska.
- Encased equipment such as traffic control devices and signal control systems for rail service might fail due to higher temperatures inside the enclosure.

Operations

- Increased electricity usage and power outages during heat waves might affect the electrical power supply to rail operations and supporting ancillary assets (such as electronic signing) for highway operations.
- Low water levels could significantly curtail barge operations along major river arteries as well as lock and dam operations.
- Extended periods of high temperatures will affect the health of employees who work long hours outdoors, such as those working on infrastructure reconstruction and maintenance activities.
- Right-of-way landscaping and vegetation will have to be more drought resistant and able to survive longer periods of high temperatures.
- Other water-use activities in a transportation agency might have to be curtailed, at least on a temporary basis (e.g., washing of transit vehicles).
- Extreme temperatures will create dangerous conditions for many users of the transportation system, placing greater emphasis on the use of air conditioning for transit vehicles and stations and on increased use of green design approaches.
- Extreme temperatures could result in increased maintenance activities, such as replacing tracks that have buckled and pavement sections that have experienced heave, as well as removing landslides and erosion that occur with extreme precipitation events after drought or extreme temperatures have dried out the soil.

- Drought-induced wildfires and/or dust storms can create dangerous blackout conditions for road users.
- Airplane operations in high-temperature environments might have to be reconsidered due to less lift available in higher elevations to allow a plane to take off. (In Phoenix, Arizona, flights have been canceled due to extreme temperatures and officials' concern that the runway was not long enough for the planes to take off.)
- Extended periods of high temperatures will likely result in changes in rail operations, at a minimum requiring mandatory reduced speeds in areas where the track has been exposed to high temperatures over many days.
- Similarly, extended periods of high temperatures will negatively affect bicycle use and the desire and propensity of individuals to walk outdoors.

Transportation officials are increasingly becoming interested in the implications of future climate change on their agency's operations. As this interest increases, it is likely that additional guidance will become available on how to plan, design, operate, and maintain transportation systems such that they are more resilient in the face of increasing climate change and extreme weather risks (see, for example, FHWA, 2016, 2017a; Meyer and Weigel, 2011; and Meyer et al., 2014),

Climate change, public health, and transportation

The interface among climate change, public health, and transportation occurs in three major areas, which have been largely covered in other sections of the book.

1. Weather-related conditions (e.g., high winds, dust storms, sudden floods, blinding rain, or snow) are factors contributing to fatalities and injuries that were discussed in Chapter 7 as being of concern to both transportation and public health officials. In many cases, the weather-related event itself can result in fatalities. For example, the National Weather Service (NWS) reported 116 people killed in floods, 106 from extreme heat, 43 from hurricanes, and 20 from high winds in 2018 (note: this report did not include updated estimated deaths from Hurricane Maria in Puerto Rico). Fifty percent of the 418 flood deaths from 2015 to 2017 occurred in vehicles (NWS, 2018).
2. Transportation provides accessibility to all sorts of land uses, including medical and health care facilities. Widespread disruptions due to extreme weather can cut access to such facilities seriously affecting the ability of health caregivers to provide medical help. This also impacts the supply chain of medical supplies and personnel trying to access the affected areas. During the recovery period, transportation facilities and service provide the channel for water and food to reach disaster zones, as well as supporting

the social determinants of health that are stressed during times of disruption.

3. Roads, and in some cases transit services, helicopters, and airplanes, can provide a means of evacuating either areas that are likely to face a disaster (e.g., hurricane) or those that have experienced one (e.g., earthquake). Having a means of evacuation is especially important when there is only one way to leave. A wildfire in California in 2018, for example, surrounded the only road serving isolated campgrounds and other recreational sites that were later burned as well, resulting in fatalities for those not heeding the advice to evacuate before the fire reached those sites. Hurricane Katrina is partially remembered for large groups of the population stranded in New Orleans with no means to evacuate (the city has since identified bus stops designated for pickups of those without vehicles prior to a hurricane hitting the region).

   Another (nonclimate change) example is the effort of the Oregon DOT to establish routes into the state that would survive a major earthquake given that the major interstate serving the state (I-5) is expected to be destroyed in many locations (ODOT, 2014). Alternate routes are being hardened; redundant command and control centers have been established; and prepositioning of emergency supplies has occurred to provide access to water, food, and medical supplies assuming that the road network is disrupted.

4. In some cases, transportation facilities and services can provide refuge for those seeking shelter. In the aftermath of Hurricane Katrina, many people sought higher elevations, that is, bridges, to avoid rising flood waters. In many cities during heat waves, those without air conditioning ride air-conditioned buses to avoid the heat (some transit agencies offer free trips for this purpose); during extreme cold, many likewise ride the transit system seeking heat.

5. Transportation agencies are often one of the few agencies with monitoring and public information capabilities in forewarning the population about an impending disaster and to communicate after a disaster occurs. These include communications about emergency routing, roadway closures, wide-area alerts, early warnings, evacuation, re-entry into disaster zones, and disaster travel information. Variable message signs that are common on major highways throughout the world can be used to convey messages concerning the locations of shelters and the most efficient paths through a road network.

6. In the aftermath of a major disaster, transportation agencies provide the physical barriers to isolate areas that are targeted for recovery to keep out those who do not belong. In addition, one of the key challenges facing many communities after a disaster is removing levels of debris that far exceed the capacity of a community to remove. State DOTs have the

capability to transfer resources from one location to another and thus have become an important source of debris removal (if authorized to do so by the legislature). As an example of one state's efforts in debris removal, the Georgia DOT has formed "strike teams" for every segment of the state's freeway system that will respond quickly to system disruptions; staff from the state's forestry service are part of these strike teams in order to bring power saws to remove downed trees, often a major obstacle in reopening a road.

Summary

The public health consequences of climate change represent potentially some of the greatest challenges society might face in future years. This is especially the case for (1) the transmission of diseases and environmental infections that will follow the changing environmental conditions associated with a changing climate and (2) the aftermath of major weather disasters that on average will likely be more powerful than storms of the past. The public health community has many policy, program, and prevention options for dealing with climate change impacts (Watts et al., 2015). For example, Frumkin et al. (2008) suggest public health professionals can "explain the health rationale for climate change mitigation in terms of reduced morbidity and mortality …. can provide evidence on the health impacts of various approaches to climate change mitigation (including co-benefits and disbenefits) … and should play a major role in developing plans that address health threats related to climate change." In many of these actions, transportation service and infrastructure can play a critical role in minimizing the public health consequences of a changing climate.

All-hazards approach in responding to major incidents/ disasters

Major disasters and community disruptions have common characteristics in terms of how government agencies can prepare, respond, and recover from the aftermath. An emphasis on preparation, a unified command and control structure, a focus on public health and medical needs, compatible communication systems, and the like are common no matter what type of disruption will occur. In some cases, one type of disaster follows another, often with the first one exacerbating the second. For example, drought often leads to wildfires, which if followed by heavy precipitation can lead to more serious flooding (due to the destruction of land cover) and massive erosion (e.g., landslides). An "all-hazards" approach has been adopted by many of the participants in disaster response (for example, see CDC, undated for a hospital application) to be prepared no matter what the disruption.

Anatomy of a disaster

The underlying concept of an all-hazards approach to disasters is that preparation serves as the foundation for effective response to any type of incident. Fig. 8.4 shows a typical representation of the different phases of disaster preparation and response. For both response and recovery phases of a disaster, preparation is necessary, which is indicated on the left side of the figure. In fact, this preparation is continuous....indicating periodic updates and practicing of response and recover procedures. Also of note in the figure is the immediate response to a disaster which evolves into a recovery operation....in fact, as indicated these phases tend to overlap. The long-term recovery includes rebuilding and making changes during the rebuilding that will provide more protection if another similar disaster strikes. The other important observation from Figure 8.4 is the time frame....immediate response measured in days and perhaps weeks; intermediate response/recovery measured in weeks/months; and long-term recovery measured in months/years. The all-hazards approach to disaster preparation considers each phase of such a disaster cycle.

Legislative/regulatory foundations

At the US federal level, the Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) of 1988 established the legal and institutional system for presidential disaster declarations and for the response from federal agencies. FEMA was given the responsibility for coordinating government-wide relief efforts. DHS has lead responsibilities for incidents involving national security (Meyer, 2009). Beginning in the 1990s, the US government under the leadership of FEMA implemented the all-hazards approach for developing risk-based, all-hazard emergency operations plans. FEMA's "*Guide for All-Hazard Emergency Operations Planning*" lays out the steps that "served as a basis for effective response to any hazard that threatens any jurisdiction;

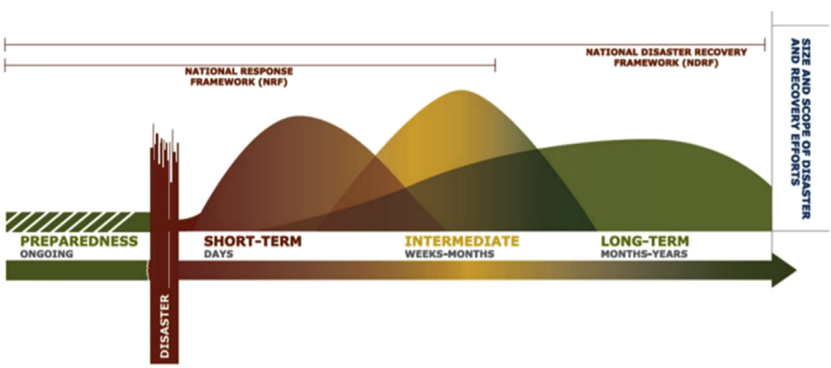

FIGURE 8.4 Phases of a disaster.

facilitated the integration of mitigation into response and recovery activities; and facilitated the coordination with the federal government during catastrophic disaster situations" (FEMA, 1996). This guide recommended specific actions in such areas as emergency public information, communications, command and control, mass care, health and medical response, and resource management.

The guide also defined a "concept of operations" that would ensure that the necessary planning and coordination be accomplished prior to the occurrence of a disaster to facilitate the management of health and medical services during disasters. The concept of operations was to include such things as establishing a medical command post at a disaster site that:

- Coordinated health and medical response team efforts.
- Triaged the injured, if appropriate.
- Provided medical care and transport for the injured.
- Identified, transported, and handled the deceased.
- Established holding and treatment areas for the injured.
- Isolated, decontaminated, and treated victims of hazardous chemical or infectious diseases, as needed.
- Identified hazardous chemicals or infectious diseases, controlling their spread, and reporting their presence to appropriate state and federal health or environmental authorities.
- Issued health and medical advisories to the public on such matters as emergency water supplies, waste disposal, mass feeding services, disease vectors, immunizations, disinfection, and others (FEMA, 1996).

The guide recognized the need to coordinate the many different agencies and groups that might be involved with a disaster response. Table 8.10 shows the types of agencies that were identified for two areas: "mass care" and "health and medical."

Federal preparations since the 1990s have been in response to Presidential Policy Directives especially relating to national preparedness, related FEMA policies, and DHS initiatives. Several key concepts in the DHS directives include:

National Incident Management System (NIMS): A nationwide approach for all governments, private companies and nongovernmental organizations (NGOs) to prepare for, respond to, and recover from domestic incidents. The focus is on providing interoperability and compatibility among those involved with a domestic incident including the creation of an Incident Command Structure (ICS) (FHWA, 2017b).

National Response Plan (NRP): An "all-discipline, all-hazards" plan that provides for the coordination of a federal response to a domestic incident. The plan includes annexes for specialized circumstances. Specific government and private sector participants are assigned responsibility for functional roles in what are called Emergency Support Functions (ESFs) (DHS, 2008).

TABLE 8.10 Health-oriented participants in all-hazards planning and response, FEMA.

Mass care	Health and medical
Mass care coordinator	Health and medical coordinator
Mass care facility manager	Emergency medical services (EMS)
Emergency manager	Hospitals
Salvation Army (local)	Public health officer
Nonprofit public service organizations	Environmental health officer
Education dept./school superintendent	Mental health agencies
Public works	Mortuary services
Public information officer (PIO)	Social service agencies
Agricultural extension agent	
American Red Cross (local)	
Law enforcement/corrections department	
Military department	
Animal care and control agency	

Source: (FEMA, 1996).

Emergency Support Functions: The primary operational-level mechanisms for federal agencies to provide assistance to other governments. For example, evacuation efforts would be supported under several ESFs including transportation, communication, mass care, and emergency management (FHWA, 2017b).

Institutional/organizational coordination and collaboration

If as was noted earlier that "preparation" serves as the foundation for effective response to disasters, then coordination and collaboration serve as the basis for effective preparation. As noted by the FHWA,

> *"Leaders at all levels must communicate and actively support engaged partnerships by developing shared goals and aligning capabilities so that no one is overwhelmed in times of crisis .... Incidents must be managed at the lowest possible jurisdictional level and supported by additional capabilities when needed*
>
> (FHWA, 2017b)

A recent review of all-hazards approaches to nonnuclear incidents by the Organization for Economic Cooperation and Development (OECD, 2018) emphasized this point in a review of incidents in member OECD countries. The following selected lessons learned in this review provide an excellent overview of the characteristics of an all-hazards approach to incident/disaster response that should be considered by those developing such a strategy.

- Legislation and regulations, while necessary, are not sufficient to ensure the prevention of accidents or adequate preparedness. It is therefore important for stakeholders to undertake additional initiatives and learn from the experience of others in different fields of work.
- A common issue shared by both the nuclear and nonnuclear industries is that of identifying a wide range of accident scenarios, from design-based to beyond-design—based accidents. Consideration of such a broad range of accident scenarios ensures that planning efforts are robust and provide for adequate protection of public health and safety.
- Promoting forward-looking risk governance that takes into account complex risks is important. In evaluating risk exposure, countries may want to not only rely on past disruptive shocks and linear risk modeling, but also consider evolving risk patterns, including demographic, economic, technological and environmental drivers, as well as their interdependencies and potential cascading impacts.
- Training and emergency drills have also been identified as essential for successful emergency response both on-site and off-site.
- It is very important to select appropriate personnel protection measures such as equipment for emergency responders, as well as the means of improving their awareness of the hazards surrounding the event.
- Governments must develop crisis-management capacities to cope with the complexity, novelty, ambiguity, and uncertainty characterizing many modern crises. Emergency response plans are necessary tools for conventional crisis management.
- Using social media effectively in crisis communication requires that appropriate resources be devoted to the management of social network messaging during the event. It is important to ensure that the information circulating in various social media platforms is accurate because accurate information leads to public trust in officials (see OECD, 2015 for a good discussion of the use of social media).
- Engaging the private sector in crisis-management efforts is crucial, particularly when the scale and complexity of a crisis requires a "whole-of-society" approach.
- Leaders must be identified prior to the crisis, and they along with their teams, organizations, and key partners must be sufficiently prepared to cope with the challenges presented by the crisis.

- On-site emergency plans for accidents involving hazardous materials should take natural hazard risks into account. Off-site emergency response plans for hazardous industries in natural hazard-prone areas should consider the impact of hazardous material releases on populations and on rescue operations. The vulnerability of emergency response resources to natural events and hazardous material releases should be assessed. Medical services should be involved in the preparation of the external emergency plan.
- Health effects from disasters are far more than the sum of their physical or psychological health effects, including posttraumatic stress disorder. Medically unexplained symptoms or syndromes may be the most prominent negative health outcome.

Within the context of this need for collaboration and coordination, both public health and transportation officials have important roles to play. In both cases, the command structure will likely be led by either FEMA or DHS depending on circumstances, but as indicated in guidance from both agencies public health and transportation agencies are important participants in the phases of a disaster shown in Fig. 8.4.

Discussion questions

1. Chapter 2 discussed social determinants of health and their influence on public health. Using the concepts in Chapter 2, identify those factors that could influence the transmission of an epidemic in your community (assume the characteristics of the disease being transmitted). What are the socioeconomic characteristics of your *community* that would encourage a spreading of the epidemic? What are the characteristics of your community's *transportation system* that would encourage (or discourage) a spreading of the epidemic?
2. Identify the key characteristics and roles of different actors in your agency's hazardous materials spill protocol/plan? Create a hypothetical "incident" in your organization and describe who does what and on what timeframe.
3. Using Fig. 8.4, describe the key differences in each phase of the "anatomy of a disaster" as they relate to transportation system disruption for a (1) natural disaster and (2) a terrorist attack. What agencies would be involved in each type of incident? What types of information would be necessary as part of the preincident planning? What types of mitigation strategies would be considered for each incident?
4. Climate change will likely have significant public health consequences and disruptive effects on transportation systems. Identify future climate forecasts for your region (if there are not specific forecasts for your community, use the *Fourth US National Climate Assessment* background forecasts for

your state). Choose one climate stressor (e.g., heat, precipitation, sea level rise [if on a coast], etc.) and describe what impacts the forecasted level of this stressor will have on public health in your community; On your community's transportation system; jointly on public health and transportation.

5. Identify what types of organizational and institutional strategies can be used to foster collaboration among public health and transportation agencies in dealing with community disruption. What are the advantages and disadvantages of each?
6. You have been asked to write a climate change/public health report for your community, with special focus on how climatic changes might affect community infrastructure and services. Outline how this report should be organized. What types of topics should be included?

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