6. Transportation Sector

6.1. Introduction

Transportation systems play a critical role in supporting other critical services and infrastructure systems. Hospitals, fire stations, police, and other emergency response systems all depend on the transportation systems before, during, and after a disaster. Evacuation depends on the capacity of roads, waterways, and airports as well as the governmental ability to manage them. Relief efforts are hindered until damage to the transportation systems has been repaired.

This chapter deals with transportation systems divided into four main categories: roads and bridges, railroads and subways, air, and marine transportation. Each of these transportation systems is important during and after a disaster for moving people and supplies (freight) to and from affected areas, and each has both common and unique vulnerabilities. Many of these systems are owned and operated at the local, state, or federal level. Each system needs to be evaluated within the context of the community or communities it serves to determine the required performance levels. Through careful consideration of specific vulnerabilities and risks, system performance and community resilience be improved and catastrophic losses can be avoided.

6.2. Performance Goals

Measures of resilience are currently based on damage levels, losses of functionality, monetary loss, and recovery time. Presented below are tables detailing recovery time targets for different critical systems. The three functionality targets are broadly defined in Table 6.2.

Performance goals are a function of the size of the transportation network as well as the role of the system within the community. This may include a small transportation network, such as several bus lines, or may extend to a large network encompassing a full state's rail, water, and air transportation systems. Table 6.1 describes the various sizes of the transportation networks addressed in this chapter.

Table 6.1. Transportation Network Size

Transportation Network Size	Description
Small	(Single bus route or train station) Serves a neighborhood or immediate vicinity to a natural hazard event.
Medium	(Subway system or small municipal airport) Serves a city or town
Large	(Large airport or major highway system) Serves a full state and may account for egress in and out of disaster area

The resilience targets provide a goal for each community to attain and are consistent across all sectors. These include minimal, functional or operational. Table 6.2 provides a description of each of these targets.

Table 6.2. Resilience Targets

Resilience Target	Condition of Transportation System
Minimal	Emergency responders, supplies, and construction crews can transport crews and materials
Functional	Functional with some closures, weight restrictions, and lower speed limits
Operational	Almost complete return to functionality

The desired performance of each transportation system will be addressed through recovery objectives by a given timeframe, as shown in Table 6.3. It is up to the community to choose the specificity that best suits its needs.

Table 6.3. Recovery Targets of Transportation Infrastructure

Transportation System or Component	Recovery Target	Time Frame
Municipal Roadways	Minimal	Hours to Days
	Functional	Days to weeks
	Operational	Weeks to months
Local Airports	Minimal	Hours to Days
	Functional	Days to weeks
	Operational	Weeks to months

6.3. Transportation Infrastructure

Many frameworks for assessing transportation infrastructure revolve around risk assessment. For the purposes of this discussion, the definition of risk is the likelihood or probability of a negative event occurring and the consequences of that negative event. [4] Thus, risk can quantitatively be measured as a function of the probability of an event occurring and some metric of the consequences or damage. Events with severe consequences or events that occur frequently may present risks that should be addressed. A transportation system may have risks due to a combination of aging effects, exposure to the climate, hazards, and loading changes due to vehicle changes in size, frequency of use, etc. [5]

Many different considerations need to be made when assessing the need for improvements to a system of infrastructure. Life safety considerations, monetary loss prevention, societal needs for the entire community may all play a part. The role that the system will play before, during, and after a disaster, especially with regard to the conditions of other transportation systems in the area and the risks they face from likely disasters will all vary uniquely for every community. In light of this, it is important for each community to prepare for disasters with regards to its own situation while considering all of the factors mentioned above.

6.3.1. Roads, Bridges, Highways and Road Tunnels

Roads, bridges, and highways are vital to the transportation infrastructure of the nation and are often deteriorated and in need of repair. Our four million miles of public roadways endured 3 trillion miles traveled by vehicles in 2011. Almost a third of our roads are in poor or mediocre condition, costing motorists who travel over them an average of $67 billion per year in repairs and operating costs. An additional $101 billion is lost each year in time and fuel due to congested roadways, which make up 42% of the total. The FHA estimates that the $91 billion invested in roads per year needs to be increased to $170 billion in order to significantly improve conditions. [6]

With respect to bridges, it is estimated that one in nine of the nation's bridges is structurally deficient, while one in four is either structurally deficient or functionally obsolete. The average age of a bridge is 42 years, meaning that 30% of bridges have exceeded their 50 year design life. Current funding is insufficient to repair the nation's large urban bridges that carry a disproportionate amount of traffic and, in many cases, represent some of the most vulnerable parts of the highway system. [6] If investment into the nation's bridges remains insufficient to keep them in good repair, the resilience of the system will continue to decrease.

Flooding, both short- and long-term, is expected to rise alongside precipitation. This increases the risk of landslides and heightens soil moisture levels in addition to the issues created by the floods themselves, which are associated with delays, and hazardous driving conditions. High soil moisture levels can compromise the integrity of the foundations for roads, bridges, and tunnels. Inundation also leads to scour and corrosion damage, which are two major modes of damage to the highway system. [7] Although flood damage can be mitigated partly with good location engineering and planning, standards for these kinds of climate-based location evaluation are not yet in place. Flood insurance maps are often used as a quasi-design standard for determination of the most risky areas, although they were never intended for that purpose. A more formal set of standards for flood risk evaluation needs to be developed. [8]

Road surfaces generally resist long-term damage from disaster events, but road foundations can fail in a number of ways. Landslides can damage roads from washouts and undercutting, wearing at the base of the road. Soil liquefaction during seismic events is one of the most destructive phenomena in a disaster, and can quickly cause a road to buckle as its foundation ceases to be solid. Soil liquefaction is a major vulnerability for all modes of transportation, but is especially notable for being one of the most damaging events that a roadway can experience. Disasters can also weaken road foundations over time with flooding, wave action, and seismic activity. [7]

Figure 1: Road undercutting in the aftermath of Hurricane Irene.

Hurricanes, among other severe weather events, can damage these systems via wind, rain, and storm surge. Long term inundation can weaken roadways, cause increased scour to foundations, accelerate corrosion of surfaces and electrical systems, and even float bridges off their decks. Scour is a particularly dangerous outcome that causes the majority of bridge failures in the United States and can result from freshwater flooding or saltwater storm surge. The FHWA requires that bridges are evaluated with respect to "100 year" and "500 year" events but, with these kinds of weather events occurring more and more frequently, this guidance may come to represent a bare minimum for a resilient design. Bridges, especially long span and cable-stayed designs, are also vulnerable to wind damage. Wave action can wear at concrete and asphalt in roadways and over many exposed fronts of bridges. Even after the waters recede, debris left behind from a disaster can lead to road closures and impact other structures. Finally, smaller parts of these systems such as signs, lighting, supports, and electrical systems are all vulnerable to storm surge, wind damage, and corrosion. [7]

Figure 2: Bridge sections slid off their moorings during Hurricane Katrina.

Bridges are even more vulnerable to climate change and severe weather than roads and highways. This is partly due to the fact that the pavement on roads and highways typically has a design life of 20 years, and thus are repaired frequently enough to adapt to changing conditions. As discussed previously, bridges are also subject to scour at their foundations, which increases with flooding and wind associated with strong storms. Longer bridges experience increased wind loads due to their increased surface area,, which can cause dramatic failure like the case of the Tacoma Narrows bridge disaster of 1940. Finally, bridges are more vulnerable to storm surge and wave action over the course of their longer design life. [8] These additional vulnerabilities oftentimes make bridges into weak points in the road network.

Although they are generally resilient by their very nature to many disasters, road tunnels are particularly vulnerable to others. In general, tunnels present more risk to life safety than other systems that have more easily accessible methods of egress. Fires in tunnels are the most deadly disasters due to the fact that the enclosed space causes decreased oxygen levels, contains toxic gasses, and channels heat like a furnace. [9] Precipitation is another threat: flooding in surrounding areas can lead to dangerously high soil moisture levels that can compromise structural integrity. [7] During long-term inundation inside a tunnel, corrosion is a major mode of damage especially to any electrical or piping infrastructure that runs through. That said, there is value in letting some tunnels flood in urban environments in order to reduce infrastructure damage elsewhere; this concept is used in the design of the Malaysian SMART tunnel, which is designed with a lower and a higher roadway and the capacity to flood its bottom half while allowing some traffic. [10] More resilient designs, and different protection measures such as inflatable tunnel plugs, may need to be employed in order to adequately mitigate the individual risk associated with each tunnel in each community. [11]

6.3.2. Rail and Subway Systems

Rail systems typically carry bulk commodities and assist in commuter services, and have seen a boom in recent years. Amtrak reported a ridership high of 31.2 million passengers in 2012, double the reported figure from 2000. Railroads transport almost half of the nation's intercity freight and about a third of our exports, both numbers that are projected to increase. Freight and passenger railroads have been increasing investing in their infrastructure even in the face of the recent recession, putting $75 billion back into the tracks since 2009. In 2010, freight railroads renewed enough miles of track to go from coast to coast. This aggressive investment policy is giving the rail system the capacity to meet future needs and represents an opportune time to build resilience into the system. [6]

Since rail systems tend to be less interconnected to each other than roadway systems, there are more key points that serve as bottlenecks to different areas. One example is the failing Virginia Avenue tunnel in Washington D.C., through which 20 to 30 cargo trains travel every day. The tunnel, now 110 years old and facing structural issues that would cost $200 million to repair, has only one rail line and thus forces many freight trains to wait while others pass through. This tunnel is just one example of a bottleneck that could be severely affected by a disaster. [12] Bottlenecks like these already annually cost the U.S. about $200 billion, 1.6% of GDP, and are projected to cost more without adding capacity along nationally significant corridors. [6] Any disruption to these points in the system could cause significant disruptions to the economy, indicating a need to build in alternate routes and thus redundancy into the system.

Figure 3: A railroad bridge in New Orleans is washed out by flooding.

Careful planning can ensure that tracks are placed along high elevations and away from potential natural or artificial hazards. Relocating transit lines to newer tracks that have been placed with more consideration to natural hazards and disaster risks can reduce vulnerability, as can keeping older tracks in good repair for redundancy. Since railways, like roadways, are replaced every 20 years on average, resilience can be built into the system then. [13] A focus on early warning systems prior to a disaster event, whether that system is implemented by the weather service or by the rail companies themselves, is essential if trains are to be moved to safer locations. As with other forms of transportation, adding forms of damage assessment can enable better prioritization of resources and thus faster recovery in a post-disaster environment. [14]

Flooding is especially problematic for subway systems, which trap the smallest rainfall into confined spaces and can experience many of the same impacts as a road tunnel. During Hurricane Sandy, the New York City subway system experienced heavy flooding; some tunnels filled up entirely while others "looked like rivers." The subways pumps were easily overwhelmed by combination of rainfall and storm surge. When power went out, the lack of redundancy in power supply stopped the pumps completely and left the subway unable to recover. The subway system had been designed around a 100 year storm, but such storms are now hitting NYC every two years on average. The lack of protective measures makes the system vulnerable to water, and the lack of pump capacity combined with a frail power supply makes it unable to recover quickly. These problems combined to severely inhibit the resilience of the subway system to the point where it will still take years for every station to reopen. [15]

RESILIENCE EXAMPLE: The New York City metro system, despite being one of the oldest transportation infrastructures in the city, showcased adaptability in its response to the 9/11 attacks. Decision making was dispersed throughout the system; station managers were used to closing down their stations and rerouting trains due to police action. As a result of leadership being empowered throughout the system, critical decision making was fast and unhindered by a chain of command. Trains were rerouted around the disaster, and when the nature of the event became clear, the subway was able to bring more trains onto outgoing tracks for evacuation. During the recovery, the system once again adapted to provide a means of transporting emergency personnel and supplies into and around the city. [3]

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6.3.3. Air

The nation's air infrastructure provides the fastest way for freight and people to move across large distances, making it particularly valuable for coordinating a nation-wide response in the aftermath of a disaster. The system is massive and negative impacts to it already have been shown to cause significant damage. The airport system moves $562 billion in cargo each year in addition to 728 million passenger flights. Commercial enplanements increased by 33 million from 2000 to 2011. By 2040, it is projected that cargo will triple and over a billion passenger flights will traverse the nation's skies. In contrast, the estimated cost of congestion and delays was almost $22 billion in 2012 and is projected to rise to $63 billion by 2040 if national spending levels on air infrastructure are stagnant. [6] Only with additional investment can the aviation infrastructure rise to meet the demands that are being placed upon it.

Unfortunately, airports tend to be more sensitive to disruptions than other forms of transportation infrastructure. For example, 70% of airport delays are due to extreme weather events, which are expected to become more frequent. [16] This can be partly attributed to the complexity of the system; more complex systems have more opportunities to fail and therefore carry more risks than are immediately obvious. [3] This makes a complete assessment of all vulnerabilities in an airport very difficult. It does not mean, however, that valuable lessons cannot be learned from previous disasters.

One of the main vulnerabilities at an airport is the runways. For example, flooding not only shuts down runways, but also can wear down infrastructure via wave action. Storms also have surges that pose a threat not only to buildings, but to the planes as well. Even outside of storm events, heat waves can cause the tarmac to buckle under the heavy loading caused by takeoff and landing. Finally, just like roadways, airport runways are exceptionally vulnerable to soil liquefaction during seismic events. [16]

Flooding, debris, snow, and ice can all easily force the closure of an airport. In 2011, the area around the Dallas Fort Worth airport received just 2.6 inches of snow right before the Super Bowl. The airport was underprepared for the event and, even though it would not typically be called a disaster, suffered significant losses. Their equipment could only clear a runway one hour after deicer had been applied, leading to the cancellation of over 300 flights. In response, the airport invested over $13 million on equipment that could clear three runways of 2 inches of snow in 14 minutes. Although this is a great example of an aggressive response to creating a more resilient airport, it also showcases how easy it is for an unexpected weather event to cause disruptions. [17]

Figure 4: Flooding closed the Chester County Airport and moved planes.

Airports play an integral role in moving people and supplies before and after a disaster. Any major disaster will accompany increased load from an evacuation. Additionally, if some airports in the area close, other airports will have to deal with redirected flights and increased loads. [16] After a disaster, federal and state aid is most quickly administered by air. These factors mean that airports are most needed when they are most vulnerable, directly before and after a disaster. Increasing disaster resilience in airports is therefore essential to increasing overall community resilience.

6.3.4. Ports, Harbors and Waterways

The U.S. Army Corps of Engineers estimates that over 95% of our trade, by volume, moves through our ports. In 2010, the ports helped export $460 billion worth of goods and import $940 billion. The U.S. has over 300 commercial harbors which process over 2.3 billion tons of cargo per year, and over 600 additional smaller harbors. Although most ports are in good condition, the terminals are in need of further investments due to the looming 2015 Panama Canal expansion. Due to the increasing size of commercial ships, many ports with shallow waterways are already inaccessible. Once the canal expansion is complete, even more ports will be left unable to take advantage of the commerce boom from servicing new, larger post-Panamax ships that will be double the size of large cargo ships in use today. [18] The need for further investment, as with the other transportation systems, means that now is the perfect time to make sustainable, resilient improvements to this critical infrastructure. [6]

The very nature of water transportation systems demands that critical infrastructure be located in vulnerable areas. Although earthquakes, storms, landslides, and tsunamis will almost always be unavoidable by planning port placement, placing ports by shallow undersea slopes can help reduce storm surge damage. In addition to strengthening the structures themselves, strengthening the ground adjacent to the water, where soil may be weak, can be beneficial. Additionally, a focus on early warning systems for ship owners and port authorities can give facilities and watercraft time to prepare or evacuate. [14]

Hurricanes, storms, and other heavy precipitation events can lead to extreme flooding and overtopping via precipitation and storm surge. This can damage structures, dislodge containers, undermine foundations, and destroy buildings outright. If hazardous chemicals are being transported, there is a risk of hazardous spills in addition to the risk of oil spills. Flooded drainage systems can cause flooding in areas that would otherwise be unaffected by a storm – not all areas and buildings are inundated by rainfall and wave action – representing a vulnerability caused by existing infrastructure. Finally, the high winds usually associated with these types of events can damage critical equipment, such as cranes, as well as structures. [19]

Figure 5: Shipping containers are displaced by high winds and storm surge.

An interview with port managers after hurricane Sandy revealed that storm surge was the biggest issue that the ports faced. The storm surge, combined with debris, slammed facilities and equipment and made road and rail access impossible even after the storm. Flooding was a major issue because all administrative offices were located on the first floors of buildings, so the water shut down the port management. In addition, flooding damaged new technology: the port had recently installed electric motors to move cranes in an effort to be more environmentally friendly, but these were all rendered inoperable. The loss of electric power shut down night lighting, nuclear detection for incoming and outgoing cargo, and traffic signals around the port. When the power did slowly return, the presence of generators running a few critical systems combined with the grid voltage and repeatedly tripped circuit breakers. In the parking lots, approximately 16,000 cars belonging to cruise passengers were flooded because there was nowhere and no one to move them. Thankfully, piers and wharves performed well because they are designed to withstand a ship impact laterally and the weight of a shipping container vertically, both forces that far exceeded loads imposed by the storm. Although there was no loss of life during the storm, this interview illustrated the sheer number of things that can go wrong in a disaster situation. Details like moving offices to the second floor, raising motors up cranes or constructing housing for them, and having a system for recovery coordination with key utilities can easily be overlooked, yet can make a huge difference. [20]

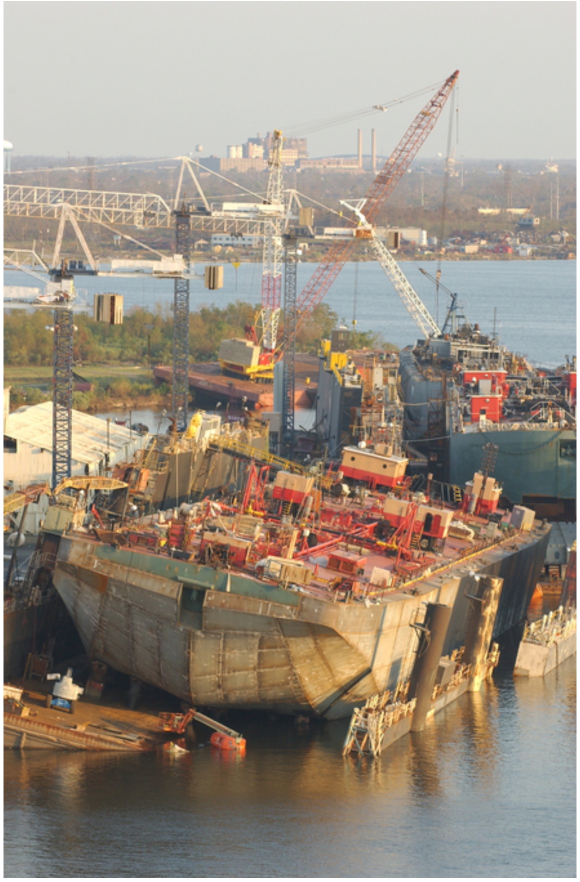

Figure 6: A large ship is forced against the port structure in New Orleans.

A unique vulnerability of maritime infrastructure is associated with sea level rise (SLR). Globally, the sea level is expected to rise by 7 to 23 inches by 2099. When combined with high tides and storm surges, this is the most probable threat to port infrastructure. Resulting changes in sediment movement can lead to siltation along channel entrances, affecting accessibility for some ships. The risk of corrosion increases as more surface area comes in contact with the water. Some susceptibility to scour and flooding is ever present and is exacerbated by SLR, though it is usually accounted for in port design. This climate change impact has the potential to exact disaster-like tolls from the maritime infrastructure. [20]

6.4. Regulatory Environment

This section is under development. Text will be included in a future draft.

6.4.1. Federal

This section is under development. Text will be included in a future draft.

6.4.1.1. Federal Highway Administration

This section is under development. Text will be included in a future draft.

6.4.1.2. Federal Transit Administration (FTA)

This section is under development. Text will be included in a future draft.

6.4.1.3. Federal Railroad Administration (FRA)

This section is under development. Text will be included in a future draft.

6.4.1.4. Federal Aviation Administration (FAA)

This section is under development. Text will be included in a future draft.

6.4.2. State

In order to maintain adequate robustness, each state and locality must adopt the appropriate codes and standards as a minimum requirement. A state's codes can be used as a form of insurance liability protection for insured design professionals, who can cite code compliance in court if necessary. These professionals are therefore less likely to stray from the legally adopted codes for the areas, which often lag behind the latest recommendation due to code cycles and lack of community adoption, for fear of losing this clear justification for their design judgment. This makes them less likely to adopt new, potentially more resilient, building practices if code adoption is deficient. [8]

6.4.3. Local

This section is under development. Text will be included in a future draft.

6.5. Standards and Codes

The failure modes discussed previously may represent key vulnerabilities in the codes that are exposed during disaster events. A summary of each transportation sector's most up-to-date codes and standards is identified in Table 6.4 alongside the vulnerabilities discussed above and possible code improvements for each.

Table 6.4. Transportation Sector Codes and Standards

Transportation Sector	Applicable Code	Vulnerability	Improvement
Roads	AASHTO "A Policy on Geometric Design of Highways and Streets" AASHTO "Standard Specifications for Highways and Bridges" FHWA Tunnel Manual		*This table is currently under development. Empty cells will be filled in a future draft.*
Bridges	AASHTO LRFD Bridge Design Specifications		
Railways	NRC Code of Federal Regulations		
Subways			
Airports	FAA Airport Design and Engineering Standards		
Ports and Harbors	UFC Design of Military Ports		

6.5.1. New Construction

This section is under development. Text to be included in a future draft.

6.5.1.1. Performance Levels

This section is under development. Text to be included in a future draft.

6.5.1.2. Hazard Levels

This section is under development. Text to be included in a future draft.

6.5.1.3. Recovery Levels

This section is under development. Text to be included in a future draft.

6.5.2. Existing Construction

This section is under development. Text to be included in a future draft.

6.5.2.1. Performance Levels

This section is under development. Text to be included in a future draft.

6.5.2.2. Hazard Levels

This section is under development. Text to be included in a future draft.

6.5.2.3. Recovery Levels

This section is under development. Text to be included in a future draft.

6.6. Resilience Needs

This section is under development. Text will be included in a future draft.

6.6.1. Standards and Codes

This section is under development. Text will be included in a future draft.

6.6.2. Practice Gaps and Research Needs

This section is under development. Text to be included in a future draft.

6.7. Reliability v. Resilience

This section is under development. Text to be included in a future draft.

6.8. Summary and Recommendations

This section is under development. Text will be included in a future draft.

6.9. References

[1] T. McAllister, "Developing Guidelines and Standards for Diaster Resilience of the Built Environment: A Research Needs Assessment," NIST, 2013.

[2] O. Gluchshenko and P. Foerster, "Performance based approach to investigate resilience and robustness of an ATM System," in *Tenth USA/Europe Air Traffic Management Research and Development Seminar*, 2013.

[3] PwC, "Rebuilding for resilience: Fortifying insfrastructure to withstand disaster," 2013.

[4] T. A. Wall and M. D. Meyer, "Risk-Based Adaptation Frameworks for Climate Change Planning in the Transportation Sector: A Synthesis of Practice," Transportation Research Board, Washington, DC, 2013.

[5] T. Hodges, "Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change

Adaptation," Federal Transit Administration, Washington, DC, 2011.

[6] American Society of Civil Engineers, "2013 Report Card for America's Infrastructure," ASCE, 2013.

[7] M. Meyer, M. Flood, J. Keller, J. Lennon, G. McVoy, C. Dorney, K. Leonard, R. Hyman and J. Smith, "Strategic Issues Facing Transportation Volume 2 - Climate Change, Extreme Weather Events, and the Highway System: A Practitioner's Guide and Research Report," Transportation Research Board, Washington, DC, 2014.

[8] M. D. Meyer, "Design Standards for U.S. Transportation Infrastructure: The Implications of Climate Change," Transportation Research Board, Washington, DC, 2008.

[9] Q. Meng and X. Qu, "Quantitative Risk Assessment Model for Fire in Road Tunnels with," University of Singapore, Singapore, 2010.

[10] ITS International, "Success of Kuala Lumpur's dual purpose tunnel," ITS International, 2012.

[11] US DHS, "35,000 Gallons of Prevention: Containing a Tunnel Flood with an Inflatable Stopper," U.S. Department of Homeland Security, 2013.

[12] L. Lazo, "Upgrading D.C.'s Virginia Avenue tunnel is key to growing East Coast rail freight, officials say," *The Washington Post,* p. 1, 16 Februrary 2013.

[13] C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. -K. Plattner, S. K. Allen, M. Tignor and P. M. Midgley, "Managing The Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergonvernmental Panel on Climate Change," Cambridge University Press, New York, 2012.

[14] The World Bank, "Building Urban Resilience: Principles, Tools and Practice," The World Bank, Washington, DC, 2012.

[15] The City of New York, "A Stronger, More Resilient New York," The City of New York, New York, 2013.

[16] Airport Cooperative Research Program, "ACRP Synthesis 33: Airport Climate Adaptation and Resilience – A Synthesis of Airport Practice," Transportation Research Board, Washington, DC, 2012.

[17] Transportation Research Board, "Critical Issues in Aviation and the Environment," Transportation Research Board, Washington, DC, 2014.

[18] NOAA Coastal Services Center, "Port Tomorrow: Resilience Planning Tool," NOAA, 2014. [Online]. Available: http://www.csc.noaa.gov/port/. [Accessed 15 June 2014].

[19] URS Corporation, "Port of Houston Authority Bayport Climate Change Study," 2012.

[20] T. H. Wakeman, "Final Report: Lessons from Hurricane Sandy for Port Resilience," The City College of New York, New York, 2013.