



# **Identifying and Reducing Barriers to Infrastructure Catastrophic Risk Insurance – Transportation Infrastructure Systems**

**Jeffrey Czajkowski**  
The Wharton School  
University of Pennsylvania

**Howard Kunreuther**  
The Wharton School  
University of Pennsylvania

**Gina Tonn**  
The Wharton School  
University of Pennsylvania  
*Corresponding author:*  
[gtonn@wharton.upenn.edu](mailto:gtonn@wharton.upenn.edu)

**(author names in alphabetical order)**

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*Center for Risk Management and Decision Processes  
The Wharton School, University of Pennsylvania*

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## EXECUTIVE SUMMARY

The U.S. transportation network is comprised of a wide range of infrastructure systems, including aviation, roads and bridges, inland waterways, ports, rail, and transit. These transportation systems are vital to the U.S. economy and way of life being responsible for the movement of people and goods locally, regionally, nationally, and internationally. Major disruptions to these transportation networks associated with natural hazards, man-made hazards, accidents, or infrastructure failure can therefore cause significant social and economic impacts. Risk management tools, including insurance and mitigation measures, can reduce the impacts and/or speed up the recovery time of such low probability but high impact infrastructure disruptions, i.e., catastrophic risks. However, recent transportation infrastructure loss experiences indicate that many of these infrastructure systems are not sufficiently insured against these types of risks. Potential pivotal contributing factors driving this transportation infrastructure catastrophic risk insurance gap are the other necessary competing risk management priorities in a typical environment of scarce operational funds being available, not to mention the role of federal disaster assistance in discouraging investments that will enhance infrastructure resilience.

This research project is concerned with identifying barriers to and opportunities for creating a robust catastrophic risk insurance market for U.S. critical infrastructure systems. This particular phase of our research – January to June, 2017 – will focus on improving our understanding of the current state of insurance and risk management of catastrophic risks associated with *transportation infrastructure systems*. In addition to a review of existing literature, we interviewed a number of key insurers (supply side) and infrastructure risk managers (demand side) dealing with significant and varied transportation systems across the country to gain insight into their catastrophic risk management strategies and insurance programs in this marketplace. Based on our findings from these efforts, we have developed seven recommendations for DHS aimed at improving the resilience toward and insurance coverage of transportation infrastructure catastrophic risks:

### Recommendations:

- #1: Continue working towards revisions of the Stafford Act
- #2: Promote alternative funding vehicles for pre-event resiliency investment that are linked to insurance premium discounts
- #3: Facilitate catastrophic risk data collection, availability, and analysis
- #4: Encourage the development of risk transfer/resilience metrics
- #5: Support research pertaining to emerging catastrophic risks such as cyber
- #6: Consider a redefinition of terrorism for coverage under the Terrorism Risk Insurance Act (TRIA)
- #7: Highlight the comprehensive operational benefits to infrastructure managers of catastrophic risk insurance coverage beyond a straightforward loss backstop

While further effort is needed to more fully flush out any one of these particular recommendations, they are all related to recurrent themes from our detailed conversations with both the supply and demand sides of the catastrophic risk insurance marketplace. Thus, we believe that when DHS addresses these recommendations in more detail, it will facilitate the development of a more robust catastrophic risk insurance marketplace for transportation systems, and hence a more resilient America.

## SECTION 1. INTRODUCTION

### 1.1 Infrastructure at Catastrophic Risk in the U.S. and the Role of Insurance

The U.S. transportation network is comprised of a wide range of infrastructure systems, including aviation, roads and bridges, inland waterways, ports, rail, and transit. These transportation systems are vital to the U.S. economy and way of life being responsible for the movement of people and goods locally, regionally, nationally, and internationally. For example, as of 2012 it is estimated that transportation (investments, purchases, employment, etc.) accounts for 9 percent of the \$13.3 trillion U.S. gross domestic product (GDP), with total transportation assets valued at \$7.7 trillion (Baylis et al, 2015).

Despite transportation's significant importance in the U.S. economic system and society-at-large, spending and investment on transportation has lagged. It is estimated that the U.S. spends about 1.6 percent of its GDP on transportation infrastructure, ranking at the bottom of its developed country counterparts (Baylis et al., 2015). Moreover, investment in infrastructure has been generally declining over time (Baylis et al., 2015). It is no surprise that an immediate consequence of this chronic underinvestment are the typical poor grades achieved on the American Society of Civil Engineers (ASCE) infrastructure report card such as the D or D- grades for aviation, inland waterways, roads, and transit (ASCE, 2017).

In parallel with this lack of U.S. infrastructure spending and investment the U.S. has seemingly entered into a new era of catastrophic risk. Restoration costs following natural and man-made disasters are increasing due to a higher degree of urbanization and a huge increase in the value at risk (Kunreuther and Michel-Kerjan, 2011; 2013). Twelve of the costliest insured catastrophes worldwide have occurred since 2000 with three of the top four taking place since 2005. Likewise during that time, U.S. presidential disaster declarations have increased five-fold. Most importantly, the proportion of total loss paid by the federal government for large-scale disaster damages has grown from 23 percent for Hurricane Hugo in 1989 to over 75 percent for Hurricane Sandy in 2012 (\$60 billion out of an estimated total cost of \$80 billion) (Michel-Kerjan, 2015).

Yet, gaining Congressional approval for disaster assistance has gone from immediate and overwhelming bipartisan support that took just three days after Hurricane Katrina in 2005 to highly contentious debates that delayed the authorization of emergency funding for three months after Hurricane Sandy, with the allocation of funds taking even longer (Michel-Kerjan, 2015). These recent long delays translate into slower recovery. Disaster relief takes a long time to channel through the system down to the end user; a large portion of Sandy's \$50 billion appropriation by Congress has still not been spent. Associated indirect costs to the regional economy increase when repairs to damaged infrastructure are postponed while Congress fights over budget offsets to support the emergency assistance. This has a direct and very serious impact on business interruption and can lead to a large number of bankruptcies among small businesses that lack financial liquidity to recovery from its disaster losses. Moreover, in the future, we can expect more extreme weather events due to climate change. The emergent and continuously evolving nature of terrorism threats posed by ISIS and homegrown terrorism, as well as cyber-threats and technological accidents, raise additional concerns about the vulnerability of our lifeline

infrastructure on which Americans and millions of businesses depend. Public and private outlays to cover the losses associated with large-scale disasters are becoming unsustainable.

In this context, enhancing the *resiliency* of the U.S. transportation system to low probability yet high impact natural and man-made disasters is paramount. Sufficient insurance coverage<sup>1</sup> of transportation systems to such catastrophic risks is one important resiliency strategy that can be employed. While insurance is by no means a panacea, it typically provides much more expedited payment to the insured party (typically a few weeks, up to a few months for the full settlement of complex losses). In addition to providing financial protection against disaster losses, insurance and other alternative risk transfer instruments can also serve as a market-based incentive mechanism by encouraging investments in mitigation measures in return for receiving lower insurance premiums through a reduction in future losses from natural and man-made catastrophes.

When disasters do occur, insurance protection will ensure that capital from insurance claims will be available to support relatively rapid repairs that will speed the recovery of the affected communities and their economies. In short, the financial and insurance sectors can play an important role in generating a new value proposition for enhancing infrastructure resilience. Specifically, finance and insurance can: (i) inform and focus attention on catastrophic risks, (ii) create economic incentives for catastrophic risk reducing measures that address the vulnerabilities and consequences associated with those risks, (iii) provide funds through mitigation loans that support investments in mitigation that foster resilience, and (iv) rapidly provide funds (insurance claims payments) that support recovery when disasters occur.

While there is no systematic data indicating the degree to which critical infrastructure is insured against catastrophic risk--which itself is a barrier to our general understanding of adequate financial protection--similar to the underinvestment in transportation infrastructure spending, there also appears to be an under-insurance of assets in the U.S. i.e., an insurance gap. For example, Lloyd's (Edwards and Davis, 2012) estimates that although the U.S. has a relatively high insurance penetration rate from a global perspective, 57 percent of losses from natural disasters during 2004 to 2011 were uninsured in the U.S., or roughly \$1.29 billion of losses per catastrophic event. 20 percent of the total damage associated with hurricanes in the U.S. in 2005 was paid by taxpayers in the U.S. in the form of federal Stafford Act recovery funding (Edwards and Davis, 2012).

One potential key contributing factor driving this infrastructure insurance gap is the role of federal disaster assistance, as it discourages investments that will enhance infrastructure resilience. More specifically, when local and state officials are confident that federal funds will be made available to make them nearly whole after a disaster strikes, they have little economic incentive prior to a disaster to expend their own limited financial resources on mitigation measures, or to purchase (sufficient) insurance that would reduce their potential losses and facilitate the recovery process. Moreover, this moral-hazard type behavior will potentially be exacerbated if natural disasters falls below infrastructure manager's threshold level of concern amidst a host of other competing priorities. For example, the Travelers Company found in their recent survey of the transportation

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<sup>1</sup> Infrastructure risk managers obtain insurance coverage across many types of risks. For purposes of our report we are referring to property and business interruption coverages associated with catastrophic risks related to natural disasters, man-made disasters, terrorism, and cyber-attacks.



industry that risks related to extreme weather/natural disasters are at the low end of the worry spectrum (Travelers Risk Index, 2016), whereas as the risks related to employee healthcare costs and benefits are rated as much more pressing. Consequently, another potential key contributing factor related to the insurance gap is that transportation infrastructure could be focused on immediate safety and reliability risks connected to their mission, as opposed to longer-term natural disaster resiliency concerns that are inherently low probability events.

Given the increasing risk to our infrastructure, insurance and other financial tools are crucial to preparing our communities for catastrophic risks. DHS, infrastructure owners and insurers need to interact with each other to better understand what factors are limiting the role that insurance can place in protecting our nation's critical infrastructure and ways to overcome these barriers. The insurance and resilience of transportation systems in the U.S. is of utmost importance for the recovery of communities after a catastrophic event, and warrants detailed examination.

## **1.2 Study Overview and Purpose**

This overall research project is concerned with identifying barriers to and opportunities for creating a robust catastrophic risk insurance market for U.S. critical infrastructure systems. This particular phase of our research – January to June, 2017 - aims to improve our understanding of the current state of insurance and risk management for transportation infrastructure systems and to develop recommendations for improving its resiliency through insurance and other risk transfer mechanisms by:

- Identifying the current practices in insuring transportation systems through mainstream insurance markets as well as via alternative risk transfer instruments. This analysis focused on both natural disaster risk and human-made catastrophes (e.g. cyber risk; terrorism risk).
- Identifying the current disincentives for investing in greater infrastructure resilience in transportation systems prior to and in the aftermath of major human-made or naturally occurring disasters. This included the prevalence of moral hazard associated with the rising proportion of total loss paid by the federal government for disaster damages.
- Outlining ways that transportation infrastructure, including both publicly and privately-owned systems, can become insurable so as to leverage the ability of insurance to create incentives for risk mitigation and to speed up available funding for relief, recovery, and reconstruction after a major disaster.
- Developing recommendations as to how the public sector and private sector can best work together to develop metrics and insurable standards for advancing resilience.
- Devising educational efforts on the value proposition for better highlighting the role of insurance in advancing greater resilience for lifeline infrastructure sectors.

Section 2 provides background on transportation infrastructure in the U.S., and an overview of the various catastrophic risks faced by the system including recent examples of catastrophic events in transportation systems and their aftermath. Section 3 describes risk transfer and resiliency for transportation systems. Section 4 describes the research methods, including key reports reviewed and interviews with insurers and infrastructure managers. Section 5 presents our key findings on needs for improving infrastructure resilience and insurance. Section 6 provides a summary of our study, recommendation for DHS, and a description of future work.

**2.1 Transportation Infrastructure in the U.S.**

A regional transportation system can be defined as the combination of vehicles, infrastructure, and operations that enable to movements of people and goods within a defined region (Cox et al. 2011). The U.S. transportation network is comprised of a wide range of infrastructure systems, including aviation, roads and bridges, inland waterways, ports, rail, and transit. These transportation systems are vital to the U.S. economy and way of life being responsible for the movement of people and goods locally, regionally, nationally, and internationally. For example, as of 2012 it is estimated that transportation (investments, purchases, employment, etc.) accounts for 9 percent of the \$13.3 trillion U.S. gross domestic product (GDP), with total transportation assets valued at \$7.7 trillion (Baylis et al, 2015). Disruptions to transportation systems have both short-term and longer-term socio-economic impacts in a community.

The U.S. system of infrastructure is extensive, with “4.1 million miles of highway, 140,000 miles of railroad, 12,000 miles of commercially active inland and inter-coastal waterways, ... more than 5,000 public use airports, more than 8,000 commercial waterway and lock facilities, 180 maritime ports, and 4,900 transit stations” (Baylis et al. 2015, pg. 16). The transportation system can be subdivided into freight and passenger transportation, and consists of the various methods of transport mentioned above. Each of these types of transportation systems are introduced briefly, with mention of resilience issues specific to each type.

*Freight:* The freight transportation system is an integrated network of infrastructure, carriers, and shippers that are involved in the design, movement, manufacture, sales, and servicing of goods. The freight system is largely a private enterprise, but much of the infrastructure that supports the system is publically built and operated (Ortiz et al. 2009). The freight transportation system involves the integration of infrastructure, vehicles, contracts, and regulations. Infrastructure components include sea and inland waterway ports, highways and roads, factories, distribution centers and the interconnections among these systems. (Ortiz et al. 2009). Public, private, and public-private entities own and operate the freight transportation system. The system is an integral part of corporate supply chains, and disruptions to the freight transportation system can potentially have widespread economic effects (Ortiz et al. 2009).

*Passenger:* Passenger transportation in the U.S. is accomplished through roads and bridges, aviation, rail, and transit networks that primarily include buses, but also subways and regional rail systems.

Freight and passenger transportation infrastructure in the U.S. takes many forms, and comprises an expansive system, as shown in Table 1.

**Table 1: Types of Transportation Infrastructure Systems in the U.S.**

Type of Transportation System	Typical Ownership	Exposure
Aviation	Private	5,000 public use
Roads and Bridges	Public	4.1 million miles of highway 614,387 bridges
Inland Waterways	Public	12,000 miles (commercially active) 8,000 commercial waterway and lock facilities
Ports	Public	180 ports
Rail	Private (freight)/Public (passenger)	140,000 miles of track
Transit	Public	4,900 stations

*Aviation:* U.S. airports serve more than two million passengers per day. Airports are a critical component in the movement of people and goods. Airports are interdependent on other sources of transportation for an efficient transportation network. There are issues with congestion in the U.S. air transportation network due in part to a lack of funds for capital improvements. There is a federally mandated cap on how much airports can charge passengers for facility expansion and renovation. There is a \$42 billion funding gap for airport investment needs between 2016 and 2025. Four sources of funding are generally used for airport development: airport cash flow; revenue and obligation bonds; federal, state, and local grants, including the Airport Improvement Program; and Passenger Facilities Charges. Resilience to catastrophic events is important for aviation systems, since they serve as a gateway to urgent relief supplies during large-scale events (ASCE 2017).

*Roads and Bridges:* U.S. roads and bridges are used extensively for both passenger and freight transportation. U.S. roads suffer from over-crowding, poor conditions, and chronic underfunding. There is currently an \$836 billion backlog of funding for highway and bridge capital needs. There are 614,387 bridges in the U.S. About 9% were rated as structurally deficient in 2016. There has been a recent increase in spending on bridge improvements, but investments in bridges are still insufficient (ASCE 2017). The U.S. population and urban centers have grown substantially, but highway capacity has expanded little, and much of the infrastructure has aged (Ortiz et al. 2009).

*Inland waterways:* The U.S. has 25,000 miles of inland waterways and 239 locks. This system delivers about 14% of all domestic freight. Inland waterways are operated and maintained by the U.S. Army Corps of Engineers (ASCE 2017).

*Ports:* The U.S. has 926 ports, and 99% of overseas trade passes through these ports. Ports are responsible for \$4.6 trillion in economic activity, which equates to about 26% of the U.S. economy. The Department of Homeland Security (DHS), U.S. Coast Guard, and Transportation Security Administration (TSA) are responsible for keeping ports secure. Federal programs support port

resiliency through information sharing and grants for resiliency projects. These programs help to create effective disaster implementation plans and strategies for restoring normal port operations after a disaster. Catastrophic events at seaports result in billions of dollars in damage and impact long-term economic activity. Ports need to balance efficiently moving goods while also maintaining secure facilities (ASCE 2017).

*Rail:* Rail delivers roughly 5 million tons of freight and approximately 85,000 passengers per day in the U.S. In general, the rail system in the U.S. can be divided into two categories: private freight railroads and intercity passenger rail, which is operated almost exclusively by Amtrak. The private freight industry owns the majority of the nation's rail infrastructure and makes continued significant capital investment to keep the network in good condition. However, passenger rail faces problems associated with aging infrastructure and insufficient funding. Amtrak covered 94% of its operating costs in 2016 with ticket sales and other revenue sources, but relies on government funding for capital investments. Rail is subject to extreme weather events, which impact infrastructure and lead to delays and issues with continuity of service. For example, during Superstorm Sandy, key tunnels under the East River and Hudson River were severely damaged (ASCE 2017).

*Transit:* The transit network is growing in the U.S., carrying 10.5 billion trips in 2015. However, overdue maintenance and underinvestment are significant issues. Buses are the most common form of public transportation, accounting for half of passenger trips in 2015. There are 15 heavy (subway or metro) systems in the U.S., and these account for the majority of non-bus trips. 10% of the nation's urban bus fleet, and 3% of the nation's rail fleet are not in a "good state of repair". The physical infrastructure is generally in worse shape, including facilities, systems, guideway elements, and stations. Transit resilience is tested by catastrophic events which impact infrastructure and can temporarily halt service (ASCE 2017).

It is important to keep in mind that these various transportation systems do not operate in isolation but rather are interconnected. As described above, the transportation system in the U.S. has distinct modes that are owned both publically and privately, moving both passengers and freight. The various modes of transportation act as a system of systems locally, regionally, and nationally. Due to the interconnectedness, and the range of geographic scales that these systems cover, planning and funding transportation systems can be challenging.

The interconnectedness of the different transportation modes can be both a source of fragility and a source of resilience. In some cases, a disruption in one system leads to a disruption in another system. For instance, a disruption in the transit system could prevent airport employees from reporting to work, causing a disruption in airport services. On the other hand, the interconnectedness of transportation systems can lead to resilience when one mode of transport can be substituted for another in the case of a disruption. For example, freight could be transported via inland waterways if rail or road transport are disrupted. Passengers can switch between different modes of transportation in areas when multiple types of passenger transport are available (e.g. subway, bus, personal vehicle).

## **2.2 Natural and Man-Made Disaster Risk in Transportation Infrastructure**

Transportation infrastructure is subject to four main types of significant disruptions: terrorist attack, infrastructure failure, major accident, and natural disaster (Ortiz et al. 2009). Infrastructure risks are greatest for systems located in areas prone to extreme events, located near climate-sensitive environmental features, or already stressed by age or demand (Wilbanks et al. 2012). Aging or poorly maintained infrastructure is subject to greater effects due to a disruption because the damage will most likely be more severe (Ortiz et al. 2009). Furthermore, few transportation infrastructure systems currently maintain any substantial level of excess capacity or redundancy (Leavitt 2006). During and after a disaster, transportation disruption is often one of the largest sources of social and economic losses. The extent of damage and the speed of restoration are critical determinants of how quickly a disaster stricken area recovers (Chang 2003).

Various significant disruptions to transportation infrastructure are described below in Table 2 to paint a picture of the wide variation in types of events and resulting disruptions that impact transportation infrastructure.

**Table 2: Examples of Transportation Infrastructure Disruptions and Outcomes**

**Boston Transit Shutdown (2015)**

- Record snowfall resulted in power outages, breakdowns, and fires in transit system
- Economic impacts associated with days of complete closure and extensive delays (Baylis 2015)

**Superstorm Sandy, New York City (2012)**

- Transportation systems including road, rail, and subway were damaged and out of service.
- Ferry terminals suffered only modest damage, and ferry transport played a large role in recovery.
- Proactive steps were taken to refuel vehicles of ferry staff so that they could get to work. An app was used to allow direct fare payment. Ferry service was added to replace several trains that were out of commission (Burke 2014).

**West Virginia Freight Derailment (2015)**

- Cars carrying crude oil derailed as a result of a snowstorm.
- Oil leaked into Kanawha River, causing water plant shutdown
- U.S. Dept. of Transportation issues new rules for rail cars carrying crude (Baylis 2015)

**Hurricane Katrina (2005)**

- \$3 billion in highway damage (Burton and Hicks 2005)
- Little effort to assist non-drivers in New Orleans evacuation. Neither public buses nor trains were deployed to evacuate people out of the city, despite rumors of Amtrak offering the use of a train for evacuation. Many public buses were unused for evacuation, and remained parked in the city where they were subsequently ruined by the flooding. The lack of transportation for non-motorists led to additional problems including costly and dangerous rescue efforts, health problems, and distrust of authority (Litman 2006).

**Kobe Earthquake (1995)**

- Port of Kobe suffered extensive damage
- Only 9 of 186 cargo handling berths were functional after the earthquake.
- All 35 container berths were damaged.
- Recovery of port business did not closely follow the restoration of damaged port facilities. Losses could be attributed to damage along with a drop in production and trade in the Kobe region associated with the earthquake.
- Port lost market share to other Japanese ports and lost substantial shares of its transshipment traffic to other world ports (Chang 2000)

**Northridge Earthquake, Los Angeles (1994)**

- Four freeway routes closed due to bridge failures
- \$1.5 billion of the \$6.5 billion in total regional economic activity loss associated with the earthquake was attributed to transportation disruption (Chang 2003).

**Hurricane Rita (2005)**

- Many Texas fuel stations ran out of gasoline because fuel truck drivers did not report to work.
- Significant delays at the two Houston area airports because more than 150 TSA screeners facing evacuation concerns did not show up for work (Litman 2006).

**West coast port lockout (2002)**

- Cost US economy \$4.7 to \$19.4 billion (\$2002) due to delays that resulted throughout the freight transport system (Ortiz 2009)

These examples of transportation infrastructure disruptions offer several lessons learned. Disruptions to passenger transportation systems can result in economic damages associated with employees unable to get to work. People reliant on public transportation can be left in harm's way if transportation assistance isn't provided during a disruption for evacuation or for other urgent transportation needs. In some cases, different modes of transportation can be substituted for others after a disaster, as in the case of additional passenger ferry service following Hurricane Sandy.

Disruptions to freight transportation can have wide-reaching economic impacts and long-term disruptions can permanently impact the economy of a region, as was the case following the Kobe earthquake. Transportation disruptions can also impact other transportation and non-transportation infrastructure systems. Many infrastructure systems are reliant on the transportation network to transport fuel, supplies and employees that are critical to the infrastructure operations. Transportation accidents can impact other infrastructure systems, as was the case in the West Virginia crude oil train derailment that impacted the local water treatment facility. Insurance and other risk transport strategies can help in encouraging physical resilience in transportation systems, so that disruptions become less frequent, and can diminish the economic impacts associated with transportation outages through both financial restitution and quicker and more complete recovery.

After Superstorm Sandy, there were three high-level actions by the federal government that demonstrated an intensified focus on incorporating resilience improvements into the recovery process. President Obama issued an executive order with 69 recommendations to coordinate the recovery effort that were designed to facilitate resilient rebuilding. Congress appropriated about \$50 billion in supplemental funds including at least five federal programs that help support resilience-building efforts. These programs included FEMA's Hazard Mitigation Grant Program (HMGP) and \$4 billion for transit resilience projects through the Public Transportation Emergency Relief Program. The Sandy Recovery Improvement Act of 2013 provided additional authorities for FEMA to fund hazard mitigation and required FEMA to provide recommendations for a national strategy to reduce the cost of future disasters (Currie 2014).

### **SECTION 3: RISK MANAGEMENT AND RESILIENCY IN TRANSPORTATION INFRASTRUCTURE SYSTEMS**

Section 2.2 provided several examples of the numerous catastrophic risks that transportation infrastructure managers face, as well as some initial insights into what resiliency efforts can be undertaken to reduce them. Building on the lessons learned from dealing with damage to transportation infrastructure systems following Hurricane Sandy and other disasters in the U.S. and abroad, we now focus on what can generally be done to manage these risks, specifically highlighting the role of insurance and resiliency.

#### **3.1 Risk Management of Infrastructure Systems**

Risk management for infrastructure systems first involves identifying and evaluating risks in terms of their probability of occurrence and expected impact. Once risks are identified and evaluated, there are three overall strategies for managing risk: avoid, control, or transfer/finance. Risk avoidance involves eliminating hazards, activities, or exposures that can negatively impact an infrastructure system. When risks cannot be avoided (as they often cannot for transportation infrastructure), they can be controlled through mitigation including the building in of redundancies into the system. Mitigation measures can serve to reduce the frequency or severity of losses, and can occur before, during, or after a disruptive event. For example, prior to a natural hazard event, transportation infrastructure can be built up to the latest standards and codes. After an event, there could be a systematic checklist in place for operators to follow in order to facilitate recovery of the system. Finally, after identified risks have been controlled as best as can be done, if at all, the residual un-prevented loss can be transferred through various risk financing mechanisms. That is, financing risk involves taking proactive steps to transfer the un-prevented loss aspects of a potential disruptive event. Transfer/financing of risk can occur through three broad methods – insurance (including reinsurance), self-insurance, or pooling of risks (Kaddatz 1995).

A proper risk management strategy will assess the benefits and costs trade-offs associated with these various strategies now and into the future. Kaddatz (1995) discusses a number of benefit-cost factors related to the selection of insurance, self-insurance, and pooling. For example, self-insurance provides a high level of control over risk services and claims handling, but a low level of cost stability. Commercial insurance comes at a higher cost and provides lower levels of control over risk services and claims handling. However, commercial insurance often offers the advantage of risk management services. Insurers are experienced in identifying, analyzing, and modeling risks, and can often help their customers better understand risks and develop strategies to manage them (Kaddatz 1995). In addition, risk management strategies including emergency planning, insurance, and recovery planning are needed to reduce losses after a catastrophic event.

Finally, in certain extreme cases, the federal government can be a source of external risk financing. FEMA, or other designated agencies, such as the Federal Transit Authority (FTA) can provide public assistance or emergency relief following a presidential declaration of a disaster. This was the case with the Metropolitan Transit Authority (MTA) of New York following Hurricane Sandy. The MTA is a public benefit corporation responsible for public transportation and suffered over \$5 billion in damages during Sandy, notably damage to rail and subway systems, tunnels, stations, and equipment. The MTA's insurance paid out \$1 billion for Superstorm Sandy. As a result of the



Stafford Act, the MTA received \$4.2 billion in relief from the Federal Transit Authority (FTA) that included \$898 million for resiliency improvements and an additional \$3.7 million from FEMA for repairs to MTA bridges and tunnels.

**Table 3: MTA Recovery Funding, Superstorm Sandy (FTA 2016)**

<b>Source of Recovery Funding</b>	<b>Amount</b>
Insurance	\$1,000 million
FTA	\$4,200 million
FEMA	\$4 million

In addition to the recovery funding shown in Table 3, the MTA received extensive resilience funding, described in Table 4. The MTA established a Sandy Recovery and Resiliency Division with one goal being to protect all points where the subway system could be flooded in a future storm ([web.mta.info](http://web.mta.info)).

**Table 4: MTA Resilience Funding, Superstorm Sandy (FTA 2016)**

<b>Allocation Identifier</b>	<b>Amount</b>
D2013-RESL-016 (Emergency Communication Enhancements)	\$75 million
D2013-RESL-017 (Flood Mitigation in Yards)	\$617 million
D2013-RESL-018 (Hardening of Substations in Flood Prone Areas and Purchase of Mobile Substations)	\$112 million
D2013-RESL-019 (Protection of Tunnel Portals and Internal Tunnel Sealing)	\$43 million
D2013-RESL-020 (Flood Resiliency for Long Island City Yard)	\$19 million
D2013-RESL-021 (Flood Resiliency for Critical Support Facilities)	\$24 million
D2013-RESL-022 (Protection of Street Level Openings in Flood Prone Areas)	\$301 million
D2013-RESL-023 (Metro-North Railroad Power and Signals Resiliency Improvements)	\$38 million
D2013-RESL-024 (Internal Station Hardening)	\$20 million
D2013-RESL-025 (Pumping Capacity Improvements)	\$24 million
D2013-RESL-026 (Right-of-Way Equipment Hardening in Flood-Prone Areas)	\$64 million
D2013-RESL-027 (New York-New Jersey River to Rail Resiliency (R4) Project)	\$81 million
D2013-RESL-028 (Rockaway Line Protections)	\$137 million
D2013-RESL-029 (Flood Resiliency for Critical Bus Depots)	\$45 million
Total	\$1,600 million

In addition to the MTA funding, the FTA spent \$2.3 billion for Sandy recovery, allocated to transit systems in Connecticut, Massachusetts, New Jersey Pennsylvania, and Rhode Island. They also allocated \$10 billion following Sandy for transit resiliency projects in Connecticut, Washington

D.C., Massachusetts, New Hampshire, New Jersey, New York, and Pennsylvania ([www.transit.dot.gov](http://www.transit.dot.gov)).

The tremendous expense to taxpayers via the Stafford Act along with the substantial business interruptions associated with Sandy highlights the need for improvements in infrastructure resiliency. These improvements may be achieved through financial/insurance mechanisms coupled with regulatory mechanisms. In addition to the high cost of disaster relief associated with Hurricane Sandy, there was a high cost on the insurance side. Total insured losses associated with Sandy are roughly \$35 billion. Roughly \$20 to \$25 million of this cost was on private insurance, with the rest falling under the NFIP.

### **3.2 Focus on the Role of Insurance in Protecting Infrastructure**

The initial phase of this project (Kunreuther et al. 2016) involved a series of interviews with insurance executives to better understand the supply sides of this specific insurance market. In the first stage, we focused on the energy and rail transportation sectors. In our preliminary phase we found that only a handful of insurers actually specialize in such insurance products (e.g., Zurich, AIG, Lloyd's, FM Global). Moreover, infrastructure owners need to purchase different policies for different types of hazards they are facing. For instance, terrorism insurance is purchased independently of flood or earthquake coverage with different deductibles, limits, premiums and exclusions for each risk. Some firms do not qualify for insurance if they have not undertaken the minimum mitigation standards established by insurers for the infrastructure to be insurable and offer a lower deductible or higher limit on an insurance policy than reducing premiums if mitigation measures are undertaken.

Insurers must balance the need for reasonable premiums to attract clients with the total cost of risk (administrative cost, cost of capital, minimum return to their shareholders) that meet insurance regulation and provide an attractive return to their shareholders. As such, premiums on a given policy do not only depend on the level of risk the insured faces but also on the degree of concentration of risks the insurer has in given locations. For instance, the premiums for two transportation systems are likely to be lower for each if they are thousands of miles apart on both coasts than if they are located in the same geographical area since in the latter case the insurer could suffer losses from both systems should a hurricane hit that region. The likelihood of both coasts being hit in a given year by two disasters is much lower. Likewise, insurance premiums might increase for all insured in the aftermath of a large-scale disaster whether or not the insured entity suffered a loss. This might seem counterintuitive but if the insurer paid billions in claims, it will need to raise more capital the following year, which is likely to be costlier for it to do since the price of reinsurance is likely to have increased (unless the market has significant excess of capital).

In this regard, insured critical infrastructure often encounters contraction of their insurance coverage after a catastrophe. Prior to the September 11, 2001 terrorist attacks, Chicago's O'Hare Airport had \$750 million of terrorism insurance coverage at an annual premium of \$125,000. After the attacks, insurers offered the airport only \$150 million of coverage at an annual premium of \$6.9 million (in nominal 2002 prices). This new premium, if actuarially fair, implies the annual likelihood of a terrorist attack on O'Hare Airport to be approximately 1-in-22 (\$6.9 million/\$150

million), an extremely high probability. The airport was forced to purchase this policy since it could not operate without coverage (Kunreuther and Michel-Kerjan, 2004). This insurance capacity contraction is an important element for critical infrastructure owners to anticipate when they build their financial resiliency strategy.

On average, only approximately 30-40% of catastrophe losses have been covered by insurance over the past 10 years. Opportunities to change from a reactive to proactive policy landscape and change the role that public section authorities and funding programs play in risk reduction and resilience are important. Cash-strapped recipients of Stafford Act assistance are regularly granted waivers from insurance purchase requirements. An improvement could be to change the waiver process to allow catastrophe insurance and risk reduction projects to count toward compliance. Insurance can be used as a driver for resilience projects by timing alignment with insurance procurement and project construction dates (Vajjhala and Rhodes 2015).

Overall, we find that the interaction of the demand-supply market forces need to be better understood and explored in this work through an in-depth look at the role of insurance and resiliency in transportation infrastructure.

### **3.3 Resiliency of Transportation Infrastructure Systems**

There are various definitions of resilience and proposed methods of measuring resilience. One proposed definition of resilience is as follows: “a resilient system is able to adjust its functioning prior to, during, or following changes and disturbances, so that it can continue to perform as required after a disruption or a major mishap, and in the presence of continuous stresses” (Dekker 2008).

Measuring the resiliency of transportation systems in a post-disaster situation can be challenging. Accessibility is a performance measure with respect to how the system is serving the affected population that allows decisions to be made about repair and restoration of overall system performance (Chang 2003). An operational measure of transportation resilience is direct static economic resilience (DSER), which is the “percentage avoidance of the maximum economic disruption that a particular shock could bring about” (Cox et al. 2011). A transportation system’s ability to accommodate the needs of its most vulnerable users under extreme conditions is an important test of its effectiveness and fairness (Litman 2006).

Transportation risks are not well understood across modes, regions, and critical infrastructure sectors. This creates uncertainty about national level consequences that could occur as a result of a major disruption. Infrastructure owners and operators have a limited view of risk across systems, modes, and regions. Emerging risks associated with cyber, extreme weather, rising sea levels, aging assets, and workforce changes are not well understood. National resilience policies haven’t been well incorporated into transportation planning at multiple levels due to chronic underfunding and inability to monetize resilience for investment decisions. There is no national consensus on the need for investment in resilient transportation infrastructure in part due to limited understanding of the value of resilience. The uncertainty about emerging risks make it difficult for owners and operators to invest in resilience (Baylis et al. 2015).

### 3.3.1 Increasing Transportation System Resilience

The ability of a transportation system to adapt to a shock is related to three concepts: 1) vulnerability to unpredictable shocks, 2) resources available to a system to help it change, and 3) rigidity versus flexibility of relationships in the system (Cox et al. 2011). There are a number of strategies to reduce losses from transportation system disruptions. These include things like conservation (maintaining services with fewer resources), input substitution (shifting to other transportation models), supply inventories, and excess capacity or redundancy (Cox et al. 2011).

Flexibility, such as the opportunity to shift freight from truck to rail, and vice versa reduces corporate vulnerabilities and provides a competitive advantage (Ortiz et al. 2009). Excess capacity in a system allows it to more easily accommodate a disruption and therefore makes it more resilient (Ortiz et al. 2009). Resilience in a transportation system can also be improved by incorporating adaptive capacity in planning and explicitly including both freight and passenger traffic in planning (Ortiz et al. 2009). A study by Aerts et al. (2014) found that protection of critical infrastructure systems is one of the most cost effective measures for reducing flood damage in New York.

Litman (2006) suggests a number of ways to increase transportation system resilience:

- Include disaster response as part of all transportation planning.
- Value diversity, flexibility, and redundancy in transportation systems.
- Design transportation facilities to withstand extreme conditions.
- Create systems that include multiple links to each destination, such as multiple rail lines, roads, paths, and bridges.
- Design critical components of the transportation system to be “fail-safe, self-correcting, repairable, redundant, and autonomous”.

A report by the National Infrastructure Advisory Council (Baylis et al. 2015) offers three key recommendations for improving transportation infrastructure resilience:

1. Develop a baseline of current risks and the Federal vision for transportation resilience.
2. Develop tools and models to better understand and plan for emerging risks and interdependencies.
3. Operationalize resilience by increasing funding and implement effective practices and processes (a culture of resilience).

A report by Lloyd’s (2017) suggests the following ways to improve resilience:

- Promote integrated planning
- Value ecosystem services
- Prioritize emergency preparedness
- Design for robustness
- Increase diversity
- Incorporate redundancy
- Invest in information management
- Maintain assets
- Expand disaster risk management

### **3.3.2 Interdependency issues regarding Resiliency**

The resilience of cities after a disaster is largely determined by the functioning of complex infrastructure systems with interdependence (Chang et al. 2014). Infrastructure interdependencies can be categorized as physical, cyber, geographic, and logical (encompassing other interdependencies such as those related to human behavior). Alternately, they are classified as functional (including physical, cyber, and logical) or geographical (Johansson and Hassel 2010). In a study of interdependencies in critical infrastructure, electricity and transportation infrastructure were found to be the most significant to communities and associated industries (Ho Oh 2010). Normal operation of transportation infrastructure requires steady supply of energy (Bigger 2009).

Infrastructure providers have little incentive to be concerned with the effects of disruptions in their system on dependent infrastructure. Due to security concerns, critical infrastructure organizations don't share information that could be helpful for preparedness planning. Infrastructure organizations generally are much more aware of "upstream" infrastructure than "downstream" infrastructure (Chang et al. 2014).

During the 2004 hurricanes in Florida, significant infrastructure interdependency issues were apparent. Transportation outages impacted fuel delivery and resupply. Repair and refueling of communications sites were also impacted by transportation outages due to loss of transportation facilities and routes. Chlorine supply for water and wastewater plants was impacted by rail outages. Emergency vehicle service and access was reduced due to closed streets, highways, and bridges (Bigger 2009). Closed loop interdependencies were also observed. Power outages in the distribution system led to failure of local railroad control signals and highway-railroad crossing signals, leading to rail outages in the area. This impacted delivery of coal to a power plant, impacting electricity generation (Bigger 2009).

## SECTION 4. RESEARCH METHODS AND OVERVIEW

Our research on the role of insurance in providing financial protection against infrastructure damage of transportation facilities and encouraging investment in loss reduction measures had the following two thrusts: (1) review of technical reports and literature relevant to infrastructure resilience, and (2) interviews with managers from the insurance and infrastructure sector. Importantly, given the background from section 3 on the various risk management and resiliency strategies available, here we begin to move to understanding better what risk management practices are actually occurring in the transportation infrastructure system sector. We first summarize findings and approach from both of these thrusts in the next two sections.

### 4.1 Key Reports

Government, infrastructure organizations, and the insurance industry have produced reports that are highly relevant to the topic of transportation infrastructure resilience and insurance. Some of the key reports used in this study are noted here:

- **Airport Insurance Coverage and Risk Management Practices**, Transportation Research Board – Airport Cooperative Research Program (Rakich et al, 2011) – This report describes a survey of airport risk managers and their insurance practices and strategies. A summary of the findings of this study is provided in the box on page 30.
- **Future Cities: Building Infrastructure Resilience** (Lloyd’s 2017) – This report describes infrastructure resilience needs from an insurance perspective including case studies and suggested means to enhance infrastructure resilience.
- **National Infrastructure Advisory Council – Transportation Sector Resilience, Final Report and Recommendations** (Baylis et al. 2015) – This report describes the importance of transportation infrastructure resilience, including a focus on emerging risks. It provides recommendations regarding understanding systemic risks incorporating resilience into operational practice, and investing in resilient infrastructure.
- **Leveraging Catastrophe Bonds as a Mechanism for Resilient Infrastructure Project Finance**, ReBound (Vajjhala and Rhodes 2015) – This report describes the need for innovation in funding infrastructure resilience projects, suggesting alternative financing instruments for resilience projects.
- **Insurance as a Risk Management Instrument for Energy Infrastructure Security and Resilience** (US Department of Energy, Office of Electricity and Energy Reliability 2013) – This report examines the role that insurance can play in managing key risks in energy infrastructure, including emerging risks. It highlights the benefits of insurance for recovery and resilience and links energy to other infrastructure sectors, including transportation.

## 4.2 Interviews

Interviews and discussions were undertaken with insurers and infrastructure managers as well as with researchers having expertise in resilience of air transport infrastructure and cyber resilience for infrastructure systems. A description of the interviewees, including their titles, organization type, and transportation focus areas are included in Table 5. Multiple people interviewed from a single organization are grouped together in the table.

**Table 5: Summary of Interviewees**

<b>Title(s)</b>	<b>Organization Type</b>	<b>Transportation Areas</b>
<b><u>Insurance</u></b>		
Head of corporate insurance partners	Reinsurance	
Manager of Transportation Services	Insurance broker	Maritime
Vice President – Risk Consulting	Insurance	Maritime
Sr. Director, Enterprise CAT strategy Sr. Vice President Catastrophe Risk	Insurance	Various
<b><u>Infrastructure Managers</u></b>		
Strategy and Sustainability planner Director of strategic planning and analyses Project Manager – Resilience Office of the General Counsel	Infrastructure	Transit (rail, subway, trolley, bus)
Sr. Manager of Risk Management	Infrastructure	Port (maritime and airport)
Environmental Engineer	Infrastructure	
Director of Risk Management	Infrastructure	Port (maritime and airport)
Sr. Program Officer Sr. Program Office	Research	Air transport
Assistant Professor	Research	Air transport

A detailed list of interview questions that guided these interviews and discussions is included as Appendix A. The interview questions from this list were tailored to reflect the expertise and characteristics of the interviewees and their companies. Two sets of questions were developed: one for insurers and one for infrastructure managers. The questions for insurers focused on current offerings and barriers to catastrophe insurance for transportation infrastructure systems. In particular, current product offerings, risk insured, layers of risk transfer, changes to insurance offerings over time, and cyber insurance were discussed. Additionally, barriers to both insurance and resilience along with quantifying risk were discussed.

Questions for infrastructure managers focused on insurance and risk transfer decisions, including types of coverage purchased, changes in coverage over time, and barriers to improved resilience and risk transfer. Post-disaster recovery was discussed, including government funding for past events, and expectations for future governmental disaster funding. Measures to reduce future losses including actions taken and planned, as well as financial strategies for future losses were discussed. Views of various risks were discussed, with discussions including cyber risk and other emerging risks.

In addition to answering these questions, several of the interviewees rated the 20 proposals for strengthening infrastructure resilience through insurance, financial, and policy tools that were developed in the first phase of this project (Kunreuther et al. 2016). The ratings for each proposal varied, but a few of the proposals were very highly ranked by more than one respondent: #2: Frame the risk differently to change behavior; #3 Build credible worst-case scenarios; #17: Adopt and enforce land ordinances and zoning codes that promote resilience; and #19: Modify the Stafford Act so public infrastructure is better insured.



## SECTION 5. FINDINGS/NEEDS/CONSISTENT THEMES

The following themes were consistently identified as key needs for improving transportation infrastructure resilience, insurance products and uptake of coverage: 1) need for more and better data; 2) need for metrics to measure resilience; 3) need for research and focus on emerging risks; and 4) impact of reliance on federal funding for disaster relief; and 5) benefits of risk engineering services of insurance; and 6) insurance as a tool for resilience financing.

### 5.1 Need for Better Data

Data availability and accessibility are key for the development of new insurance products, and for evaluating and choosing risk management and resilience measures. High quality data are important, especially considering that risks are always changing. Better data allows more accurate risk-based pricing of insurance. New and better data could enable alerts of potential losses before they occur, real-time damage assessments, faster claims processing, more automation, and more personalized insurance products and services (Lloyd's 2017).

Data also facilitate the development of multi-year insurance contracts. The needs are in data availability and accessibility, predictive analytics, and governance. The challenge in issuing multi-year policies is staying abreast of changes during the contract time-period. Multi-year contracts provide security to the client, but the insurer faces the possibility of changing risks. Are they taking on risk that they haven't seen yet? Why have a long-term policy if they need to reassess the risk during that period? Improved technology should lead to the development of dynamic insurance policies that expand and contract dependent on changes in a client's risk. In theory, with real-time data, you wouldn't need a long-term policy, just one with no end-date. Government could potentially help in this regard by supporting technology that enables real-time risk assessment.

One infrastructure manager noted that their location or region tends to drive insurance pricing for certain risks, and that any loss reduction measures that they make are not likely to be considered by insurers in pricing policies. Earthquake risk was specifically mentioned in this context. With data improvements, risk based pricing could become more practical, thus driving resilience improvements. Another insurer noted that data warehousing and aggregation across industries could be a good role for the government to play.

### 5.2 Need for Metrics

Like data, metrics are important to insurers and infrastructure managers for evaluating resilience measures and for understanding necessary or important insurance coverage types and amounts. Metrics to track resilience are needed for use in models and in underwriting (Lloyd's 2017). Resilience can be incentivized through ratings that classifies the policyholder's risk and then charging them a risk-based premium with deductibles that incentivize them to take steps to invest in risk-reducing measures. Insurers could also offer resilience services such as assisting in developing risk management strategies, quantifying the economic value of ecosystem services, emergency preparedness prioritization, guidance on enhancing infrastructure robustness and redundancy, and developing worst case scenarios (Lloyd's 2017). Metrics provide the

policyholder and insurer a framework for measuring and improving resilience and in adjusting premiums to reflect risk.

Suggested areas for metrics include (Lloyd's 2017):

- Efficacy of natural defenses
- Degree of diversity
- Asset maintenance levels
- Emergency response times
- Levels of critical resources
- Levels of independence of recovery services

Regulations can be helpful in enabling insurers to set standards that an infrastructure system needs to meet. For instance, California hospitals are required to be operational within a 36-hour time-period after a disruptive event. This regulatory requirement helps in assessing the hospital's risks when designing an insurance policy.

### **5.3 Emerging Risks**

Emerging and non-modeled risks as well as the nature of system interdependencies present substantial challenges to insurance firms (Lloyd's 2017). Three key emerging risks discussed in our interviews are climate change, cyber risk, and terrorism.

*Climate Change:* Global warming is expected to bring changes in risks to infrastructure systems associated with temperature extremes, storm and precipitation intensification and the potential for sea level rise. The uncertainty associated with climate change and its impacts is a significant challenge to insurers who need to be able to quantify the risk to determine whether it is insurable and, if so, to set a risk-based premium. Infrastructure managers must assess and factor climate change risks into short-term and long-term planning and capital projects. Some studies on impacts of climate change to infrastructure have been completed such as a multi-year study by Amtrak to understand climate change risks and their impacts in the Northeast Corridor (Amtrak 2015). Additional studies are needed.

*Cyber Risk:* The number of reported cyber incidents for transportation systems has sharply increased in recent years, as indicated on Figure 1 based on reported incidents as listed in the Advisen database. As shown on Figure 2, the highest number of cases is reported in air transportation, followed by support activities for transportation and transit. With the rising number of cyber incidents, the need and interest in insuring transportation systems against cyber incidents is also increasing.

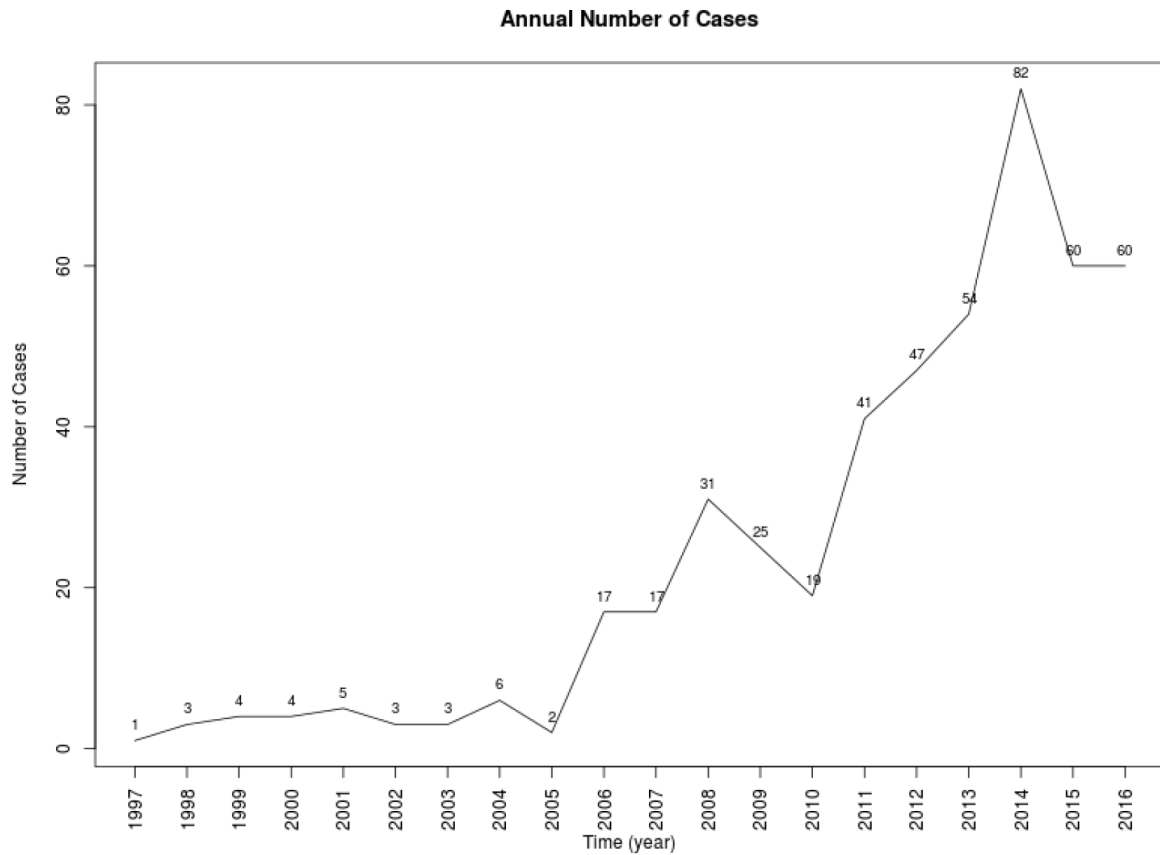


Fig. 1: Number of transportation-related cyber incidents in the U.S.

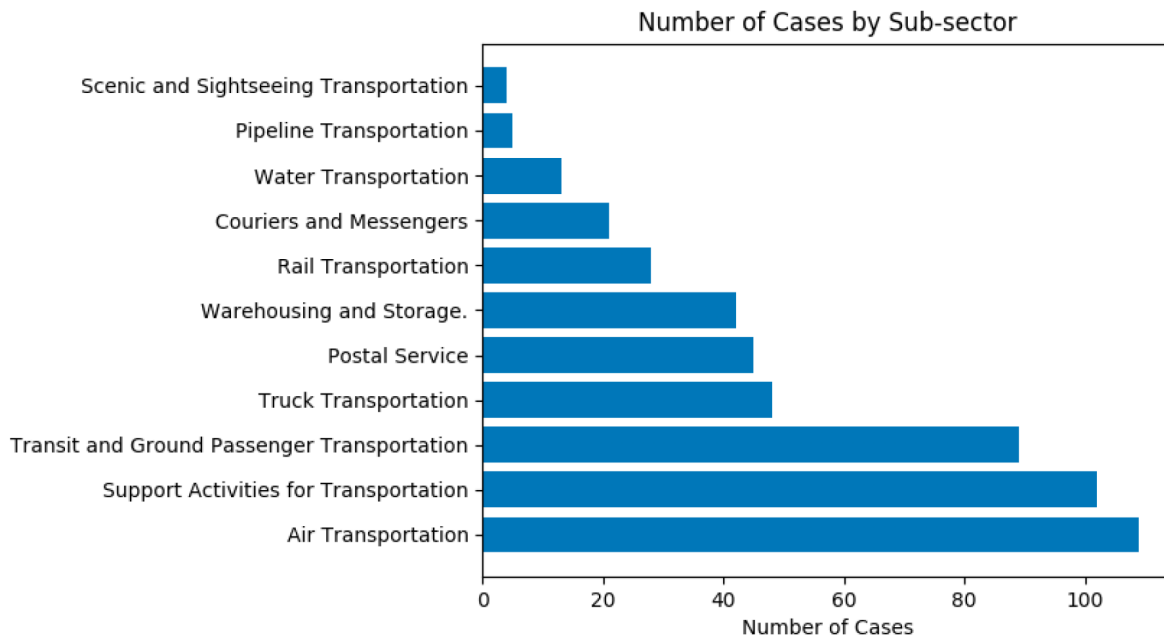


Figure 2: Number of cyber incidents by transportation sub-sector

While insurance coverage is available for cyber risk, it is difficult to get \$0.5-\$1 billion in coverage for cyber risk, and there are holes in available coverage. The insurance market still needs to mature in this area, and coverage is generally market-priced, with insurers currently unable to fully assess risk with the growth in cyber systems and digitalization. Insurers are currently developing tools and methods for assessing cyber risk. Government could play a role in setting standards for cyber risk management and creating technology for assessing cyber risks, such as models and systems for data management and sharing.

One challenge with cyber insurance is building up a diversified set of insured entities to provide a balanced portfolio of risks that are not highly correlated with respect to future disruptions so that it becomes an insurable risk. There are no geographical boundaries to cyber risk, which means that a single cyber event could impact infrastructure systems around the world. Pivotal cyber events could have far-reaching impacts, and insurance companies do not yet have a high enough confidence level for fully insuring infrastructures against losses due to cyber risk.

One insurer indicated that they are undertaking vulnerability modeling for cyber risk and are developing a plan with infrastructure managers for managing this risk. There tends to be a lot of relatively easy or inexpensive improvements in cyber security that infrastructure managers can be made aware of now before addressing issues that require complex models. Because cyber risk is still considered new and poorly understood, infrastructure managers want cyber policies with a broad range of coverage including breach reporting expenses, forensic expenses, penalties for credit card issues, ransomware, and business interruption due to hacking---areas that may be difficult for insurers to currently provide coverage.

*Terrorism:* Terrorism coverage is offered under TRIA but only applies to events that are labeled as terrorism by the Federal government. These events have high damage values (>\$1 billion), so events such as the Boston Marathon bombing were not covered. Some infrastructure managers choose not to purchase coverage when considering that only certain events are covered. Other infrastructure managers feel that their risk is concentrated in urban areas, and choose not to insure for terrorism risk if their location doesn't appear to be a target.

One insurer indicated that 10-years ago, terrorism insurance was commonly purchased for infrastructure systems. Now, purchase rates are lower as companies are being selective in buying the coverage after undertaking cost-benefit analysis. In addition to excluding terrorism risk, most commercial insurance policies generally exclude war risk.

#### **5.4 Reliance on Federal funding/role for federal government**

Infrastructure entities that we interviewed indicated that they believe that the federal government would step in to provide assistance during a catastrophic event as it is a primary component of their risk management strategy. Insurers believe that the government's role is to assist in the recovery process after a catastrophic disaster, (e.g.. if there was a cyber attack and 20 United Airlines planes went down). Furthermore, the insurance/reinsurance market is limited in the total amount of capital available to provide protection against catastrophic losses. Really high limits (>\$5 billion), aren't feasible via insurance or excess coverage. One researcher indicated that

resilience improvements are much more common in private infrastructure because they know that they cannot rely on the government as an insurer of last resort.

To be eligible for additional federal funding in the future, the Stafford Act requires that an infrastructure system become insured. One infrastructure manager noted that they were able to gain a waiver for this requirement at the state level due to the high price and limited availability of insurance. This anecdote is consistent with waivers and the role of insurance discussed in section 3.2. To further illustrate this point, in the aftermath of Sandy, the MTA could not obtain its previous insurance coverage of \$1 billion and \$500 million in storm-surge coverage would have cost twice as much for half the amount of coverage that they previously had. The MTA had to use other risk transfer mechanisms, specifically a dedicated storm-surge catastrophe bond for \$200 million (on top of its coverage for wind)..

Some reasons for not purchasing insurance are 1) affordability and 2) value (cost per \$100 coverage). The insurer doesn't always have more informed knowledge of the risk than the client. The federal government or states could assist with financial incentives (e.g. low interest loans for mitigation) and a more efficient claims payment process following a disaster to facilitate the recovery process.

## **5.5 Linking Risk Engineering and Loss Prevention Activities with Insurance**

Insurers can use risk engineering (i.e., risk control) to help pinpoint the most cost-effective way for infrastructure systems to allocate their limited funds for resilience improvements. In addition to prioritizing mitigation spending, they can estimate how these measures will impact exposure and premiums. One insurer indicated that they use risk engineering to fine-tune coverage limits and to better understand exposure for pricing purposes. This risk engineering work enabled infrastructure managers to understand their exposure, undertake loss reduction measures and obtain insurance coverage at an attractive premium. On the other hand, one infrastructure manager noted that risk engineers from insurance companies aren't always as knowledgeable about their infrastructure systems as they are.

## **5.6 Insurance as a Tool for Resilience Financing**

Insurance and reinsurance give their policyholder confidence in undertaking risk-related activities and allows them to recover when they suffer losses (Lloyd's 2017). They can use insurance as a barometer for risk, with resiliency measured by the type and amount of insurance they can obtain. Infrastructure systems have limited budgets and funding. With aging infrastructure, it is often more practical to budget to replace these systems. Normally insurance covers replacement after an event, but not cover upgrading damaged facilities.

Financing resilience improvements is key to reducing future losses. Federal funding or loans are sometimes available for resilience improvements, but one infrastructure manager noted that they often don't use this funding because it doesn't cover 100% of their costs, and it is difficult to justify the required spending necessary to cover the remaining expenditures. Loans for resilience projects would help in this regard by enabling infrastructure managers to show a measurable return on investment.

## SECTION 6. RECOMMENDATIONS AND FUTURE WORK

### 6.1 Recommendations

Based on our findings from the results of this phase of our study, we have developed seven recommendations for DHS aimed at improving their insurance coverage of transportation infrastructure catastrophic risk. While these recommendations are general in nature at this stage, they are all related to recurrent themes from our detailed conversations with both the supply and demand sides of the catastrophic risk insurance marketplace. We intend to develop more concrete details and recommendations in the next phase of this project.

#### *Recommendation #1: Continue working towards revisions of the Stafford Act*

Reliance on Stafford Act funding for catastrophic losses was noted as a key component of the risk management strategy for infrastructure systems considered in this study. While it is necessary for the government to be the insurer of last resort when a community suffers a truly catastrophic event, adjustments to the Stafford Act funding process could encourage improvements in resilience and insurance coverage. One proposed revision to the Stafford Act is to require a disaster deductible to be met prior to the receipt of recovery funds. This deductible could in the form of savings or through implementation of mitigation measures prior to a disaster. These types of modifications could encourage infrastructure managers to put additional focus on resilience.

#### *Recommendation #2: Promote alternative funding vehicles for pre-event resiliency investment linked to insurance premium discounts*

Immediate day-to-day operational and maintenance funding is an issue for many infrastructure managers. These entities struggle with how to provide funding for longer-term resiliency efforts pre-event. Low interest loans could be an option that government could offer. While an infrastructure system might not be able to afford a \$5 million resiliency improvement, with a 30 year loan at a 3% interest rate, their annual cost would be about \$250,000, which could potentially be affordable. The affordability could be enhanced by reduced insurance premiums associated with the resiliency measure.

#### *Recommendation #3: Facilitate catastrophic risk data collection, availability, and analysis*

Insurers and infrastructure managers alike noted the difficulty in relating resilience improvements to insurance premiums and cost savings. Data acquisition, sharing, and analysis is needed to enable quantification of the benefits associated with resilience improvements. Individual insurers and infrastructure managers are not in a position to obtain and synthesize these data, since it spans multiple companies and infrastructure authorities. The need for data is particularly critical in the realm of cyber risk. Availability/development of public loss models for infrastructure catastrophe modeling.

DHS could set up a data clearinghouse, similar to Verisk ISO products. The data clearinghouse could include a portal for insurers and infrastructure managers to share data on loss events and resiliency measure, which can then be used by many insurers and infrastructure managers in their

decision-making. DHS could also support the development of publically available loss models similar to those developed in the state of Florida or ongoing efforts such as OASIS <http://www.oasislmf.org/>.

***Recommendation #4: Encourage the development of risk transfer/resilience metrics***

These metrics would assist insurers with evaluating and comparing infrastructure systems and with implementing risk based pricing. They would assist infrastructure managers with assessing their financial readiness to deal with a catastrophic disruption, and with evaluating and choosing resilience measures and insurance needs. The Los Angeles Metropolitan Transit Authority has developed a Resiliency Indicator Framework (AECOM 2015). The indicators were developed to help them address climate change, including infrastructure resilience improvements and repairs.

***Recommendation #5: Support research pertaining to emerging risks***

Emerging risks are at the forefront of considerations for insurers and infrastructure risk managers. All those we interviewed mentioned emerging risks, with a focus on climate change, cyber, and terrorism-related risks. Uncertainty and data unavailability for these risks limit insurance and resilience measures. DHS can support and facilitate research to better understand and quantify these risks. DHS could fund the development of modeling tools for cyber risk.

***Recommendation #6: Consider re-definition of terrorism for Terrorism Risk Insurance Act (TRIA) coverage***

Infrastructure risk managers seem to opt out of TRIA coverage due to the restrictions on the coverage. TRIA coverage only applies to events that are officially deemed as terrorism events, leaving many terrorism-like events uncovered. Broader coverage under TRIA could potentially expand the interest in and purchase of terrorism coverage.

DHS could analyze trends in purchase of TRIA coverage to determine if purchase rates are declining. Broader coverage could be offered, or partnerships with private insurers to develop products better suited to the needs to infrastructure entities addressing a range of terrorism-like events could be developed.

***Recommendation #7: Better highlight the comprehensive operational benefits to infrastructure managers of catastrophic risk insurance coverage beyond a straightforward loss backstop***

Insurance provides financial security for infrastructure systems in light of disruptive and catastrophic events. Additional benefits associated with risk engineering and with risk and resilience financing have the potential to significantly impact the resilience of infrastructure systems in the U.S. These benefits are not insignificant and should be recognized and advertised. Role of multi-year policies/dynamic insurance policies. More effort needs to be targeted at highlighting the value of insurance business enablement vs. simply the price of the loss stop policy. DHS could develop case studies of successful risk management partnerships between infrastructure and insurance to encourage more extensive insurance coverage.

## **6.2 Future Work**

In the next phase of this project, we intend to conduct a more in-depth study of the risk management strategic decision-making process for transportation infrastructure systems in managing catastrophic risks. This will be accomplished through completion of two case studies in which we will conduct interviews with two large transportation infrastructure entities: a transit entity and a port entity

Our interviews will focus on budgeting priorities for risk management. How are risk avoidance, control, and financing activities weighted amongst each other and trade-offs compared? What are the priorities in risk management now and into the future? Which risks have a regulatory requirement for insurance purchase or other risk management expenditures, and how does this impact the prioritization of funds for other risk management expenditures?

Importantly, we will explicitly explore two key components embedded in the risk management decision-making process:

- 1) Assessing the role of behavioral biases in the purchase of catastrophic risk insurance. Do risk managers perceive that some risks are more important to manage than others? How are biases impacting risk management and purchase of insurance?

- 2) Assessing the role of moral hazard and its impact on the purchase of catastrophic risk insurance. How does the potential for Federal disaster relief factor into risk management decisions?

These two case studies will serve as a pilot study for the development of a detailed survey of transportation infrastructure risk managers and their insurance purchasing and risk management decisions. Thus, as part of the next phase of work, a detailed questionnaire on risk management and insurance priorities will be developed and refined and tested in the pilot study.

### **Acknowledgments:**

We acknowledge Dr. Jay Kesan from the University of Illinois for contributing material on cyber risk. We also thank our interviewees who each provided valuable insight for our study.



## **Broward County, FL Risk Management and Insurance**

In our interview process we identified one infrastructure entity in particular that appeared to have excellent risk management in place. Broward County, Florida has extensive transportation infrastructure including Port Everglades and the Ft. Lauderdale Airport that is subject to high levels of catastrophic risk exposure now and into the future. Port Everglades includes a large cruise ship terminal. Ft. Lauderdale Airport is the 21<sup>st</sup> busiest airport in the U.S. In recent years, Broward County has undertaken substantial reforms in their insurance portfolio as well as resiliency improvements. Their insurance portfolio includes coverage for risk associated with windstorms, terrorism, cyber, machinery, along with other risks, and their total coverage exceeds their estimated probable maximum loss. Recent resiliency improvements include terminal building and runway improvements. Due to resiliency improvements and data advances, they've been able to secure improvements in coverage with reduced premiums.

In effect, Broward County serves as an excellent example of the benefits of some of our recommendations:

Recommendation 1: Stafford Act revisions – In Broward County, they do request Federal disaster relief funding when it is available for a catastrophic event. However, they are not reliant upon this funding as part of their risk management strategy.

Recommendation 2: Alternative funding for resiliency efforts. Broward County currently has funding available to make resiliency improvements. They aren't reliant on federal funding mechanisms to make these improvements, but they exemplify the types of improvements that can be made when adequate funding is available. Their resiliency improvements are reflected in their premium amounts which have been reduced in recent years.

Recommendation 3: Data collection and analysis. The Risk Manager indicated that through continually improving data on their systems, they can better quantify risk. This allows them to purchase better insurance at a better rate.

Recommendation 5: Emerging Risks. Broward County, has coverage for cyber risk and for terrorism. As with other interviewees, they are wary of the accuracy of preliminary cyber risk models which are still in a developmental stage.

Recommendation 6: TRIA modifications. In making decisions about terrorism coverage, Broward County considers the limitations on events that are covered by TRIA insurance. Concerns about limited coverage with TRIA seem to be pervasive, and informed risk managers, such as in Broward County, seek coverage that meets the specific needs of their infrastructure system.

### **Airports and Insurance (Rakich et al. 2011)**

Some airports use insurance and attendant services and advise as their primary means of financially managing the risk of loss. Other airports use insurance to supplement other risk management practices or to help provide financial recovery from a loss. Issues in airport risk management include: lack of consistency in insurance-purchasing practice; wide variation in technical knowledge among those tasked with purchasing insurance; lack of benchmarking information within the industry; and variation in exposures.

A survey of airport managers, all from public entities, representing 20 individual airports, produced the following findings. Nearly half of airports surveyed use a broker for insurance purchase. Smaller airports tend to have long-term relationships with brokers and rely on them for advice. Larger airports have more resources and rely less on the advice of brokers for insurance-purchasing decisions. Factors influencing purchasing decisions primarily include coverage and price. Larger airports tend to shop every 3 years for insurance whereas small and medium sized airports shop annually. Cost benefit analysis and newly identified exposures motivate the purchase of new lines of coverage.

11 of 19 airports surveyed have a designated airport risk manager. Large airports tend to prioritize general liability and war and terrorism coverage. Small and medium airports also prioritize general liability coverage, but also place importance on construction and automobile liability.

Risk managers indicate that risk mitigation has become more important than insurance. Insurance has become a last resort after looking at other ways to finance risk such as retaining risk or self-insurance. Small airports tend to purchase a wide variety of coverage types, and the majority of airports purchase property, general liability, and business interruption coverage.

The purchase of war and terrorism coverage varies. War coverage is needed for occurrences such as strikes, riots, civil commotion, labor disputes, and malicious acts of sabotage. Large airports are more likely than small airports to purchase this coverage.

Larger airports tend to be self-insured for one or more lines of insurances whereas small airports do not retain risk. The decision to self-insure is based on cost-benefit analysis, the ability to control claims and manage claim costs, and affordability.

When asked about gaps in coverage, most airports indicated that they do not insure for cyber risk. Some also do not have pollution liability coverage. Additional research would most benefit small and medium sized airports since they appear not to address some significant risks.

## Resilience and Insurance at SEPTA

The Southeastern Pennsylvania Transportation Authority (SEPTA) is the sixth largest transit agency in the U.S., serving an area with a population of roughly 4 million. Ridership is approximately 1 million daily. Operating funds come primarily from the state and from fares. Capital funding is primarily state and federal. SEPTA currently has a \$5 billion backlog of “state-of-good-repair” capital needs. Despite the backlog in maintenance, SEPTA invests in resilience planning, including both safety/security and sustainability. Lacking funding specifically for resilience project, resilience improvements are wrapped into maintenance and capital projects.

Risk from catastrophic events is covered through \$0.75 billion in property insurance. SEPTA has a strong relationship with their property insurer and values the risk engineering partnership that they have with their insurance provider. They retain \$2.5 million in risk, and believe that damage above their coverage amount due to an extreme weather event would be 75% covered by FEMA. This is based on their prior experience with catastrophic events, including Hurricanes Sandy and Irene. SEPTA recently obtained coverage for cyber risk, but does not carry terrorism coverage. They are concerned about energy risk since they are dependent on their energy supplier, and are considered creating a captive to deal with this risk.

SEPTA was one of seven teams across the country selected for an FTA Pilot Program: Planning for Resilience. The program purpose is to better understand downscaled climate projects, assess key vulnerability, and develop forward-looking resilience strategies. Key risks include heat, heavy rain, snow, and tropical storms. Additionally, SEPTA was awarded \$87M (75% cost-share) in Sandy resiliency funds by the Federal Transportation Agency (FTA) for 7 resiliency projects to harden core infrastructure. Because SEPTA was planning for resilience and identifying key projects, even though they didn’t have funding for them, they were successful in obtaining this significant funding. Projects include:



Manayunk/Norristown  
Shoreline Stabilization  
(\$4.5M)



Railroad embankment  
and slope stabilization  
(\$18.7M)



Sharon Hill Line Flood  
Mitigation  
(\$3.8M)



Subway pump room  
emergency power  
(\$3.7M)



Railroad signal power  
reinforcement  
(\$32.0M)



Jenkintown Area flood  
mitigation  
(\$15.0M)



Ancillary control  
center  
(\$9.0M)

Photos from SEPTA Infrastructure Resiliency Program

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## APPENDIX A. Interview Questions

### **Interview questions for insurance industry**

#### Current offerings

1. Describe the types of transportation systems that your company currently does business with (length of involvement, successes, issues).
2. Do you insure against all types of infrastructure disruptions including natural hazards, manmade hazards (i.e. terrorism and cyber threats), accidents, and infrastructure failures? Do transportation entities purchase different policies for different hazards (e.g. flood, terrorism)?
3. What types of insurance products do you offer that are relevant to transportation infrastructure systems? Do these products link with any other resilience enhancing activities (i.e. mitigation)? How do your products address interdependencies in the system? Or how do they address geographic concentration of risk? Do your products only deal with direct property losses or indirect losses to the business?
4. Describe one of your relevant policies. Did you place this policy yourself, or are you working with a broker?
5. With whom do you interact on the policy coverage (risk management personnel, other)? How often do you interact with them? Do you or the infrastructure firm actively manage their risk and is your product tailored to this risk? How is the risk of the infrastructure system analyzed, and by whom? Do they use an insurance broker? Are the clients savvy risk consumers?
6. What has been the most significant risk dealt with under the policy?
7. Which layers of risk transfer do your transportation clients employ? (Self insurance: mitigation measures, budgeting/saving for disruptive events; Insurance; Reinsurance; Government assistance) How are these risk transfer practices taken into consideration when setting the terms of a policy?
8. What is the role of reinsurance or other alternative risk instruments in offsetting your risk in insuring them?
9. Has your insurance program changed as a result of Superstorm Sandy that hit the NY/NJ area in October 2012? If so, in what ways (e.g., lower or higher deductibles or coverage limit, higher costs per dollar of coverage, lack of availability of coverage?)
10. Has your insurance program changed as a result of any other natural or man-made damaging events? (e.g., lower or higher deductibles or coverage limit, higher costs per dollar of coverage, lack of availability of coverage)

11. What is the process to measure risks due to cyber threats caused by exploitation of known vulnerabilities in any specific technology or web-based communication?
12. Is there a good understanding of the impacts of cyber attacks on transportation infrastructure (operation/services delay, passenger injury, damages to freight, data theft)?
13. Does cyber risk management in transportation systems follow guidelines such as, NIST Risk Management Framework, ISA/IEC/ISO Standards, ICS-CERT recommendations?
14. Are there differentiated insurance policies for organizations that use archaic or outdated systems that are more vulnerable to exploitation?
15. What are the processes to ensure that organizations can identify if subsequent cyber attacks are similar to prior attacks? Are there incentives for organizations that implement changes to address known threat and ensure the same vulnerabilities are not exploited again?

#### Barriers to catastrophe insurance for transportation infrastructure

16. Broadly, transportation infrastructure includes aviation, roads and bridges, inland waterways, ports, rail, and transit. Describe (size, number of insurers, regulatory setting, private vs. public client base, profitability) the transportation insurance marketplace as a whole or any of the particular components. How has it changed over time, or how do you see it changing? What role does the quality and age of infrastructure play?
17. Is there any coverage that is currently not included in your policies, but you would like to provide in the future? What do you see as the major obstacle to providing this coverage?
18. What do you see as key barriers to enhancing the robustness of risk transfer for transportation infrastructure systems? Do you see more barriers on the supply or demand side?
19. Explain the role of quantifying the risk (how good is the modeling), profitability, premium setting, adverse selection, moral hazard, correlated risk, rating agencies. Where do you get your data?
20. What do you see as key barriers to improving resilience in the transportation infrastructure systems?
  - a. Do you see regulations as barriers?
  - b. Do you see finances as barriers?
  - c. Do you see other barriers?
21. How does the state of infrastructure repair impact insurance?



22. There are known behavioral concerns regarding decision-making for low probability/high consequence events (availability bias, threshold models, imperfect information, myopia). Do you observe these with your clients? Are there other behavioral concerns with regards to your clients' risk management?
23. When evaluating risks and setting the terms of the policy, are the cybersecurity practices of transportation entities more or less important than the cybersecurity practices of policy holders in other sectors?

We offer **20 concrete proposals** for utilizing insurance and other policy tools to foster resilience. These include efforts to *Frame the risk differently to change behavior; Build credible worst case scenarios; Use insurance to incentivize resilience investments, Design new multi-year insurance contracts; Increase resilience through means-tested insurance vouchers, through regulated rate filings, via enhanced bond ratings; Issue "resilience bonds" as a dedicated asset class; Encourage insurers to invest in resilience bonds; Support public-private partnerships for catastrophe insurance; Offer public-sector long-term mitigation grants and loans; Offer tax incentives at the local, state, and federal levels; Establish and finance a dedicated National Resilience Fund; Modify the Stafford Act to encourage insurance of public infrastructure.*

**Please rate the importance of the proposals on a scale of 1-10, with 10 representing highest importance and 1 representing lowest importance.**

## **Interview questions for transportation infrastructure managers**

### **Insurance and Risk Transfer Decisions**

1. Do you purchase insurance to cover losses from natural and man-made disasters? If “yes,” what is the deductible and coverage limit? Can you provide details or an example of one of your policies?
2. Do you buy insurance from a single company or from multiple insurers in a dedicated insurance program placed for you by an insurance broker? Explain why.
3. Do you have sufficient funds for maintenance? Do you need to choose between spending for maintenance or insurance? Or maintenance or resilience improvement?
4. Do you have any interactions with the community in your insurance or risk management decisions?
5. Are you aware of the \$200 million catastrophe bond issued by the New York’s MTA issued after Superstorm Sandy? Have you considered issuing such a cat bond?
6. Has your insurance program changed as a result of Superstorm Sandy that hit the NY/NJ area in October 2012? If so, in what ways (e.g., lower or higher deductibles or coverage limit, higher costs per dollar of coverage, lack of availability of coverage)
7. Has your insurance program changed as a result of any other natural or man-made damaging events? (e.g., lower or higher deductibles or coverage limit, higher costs per dollar of coverage, lack of availability of coverage)
8. Are you self-insured for all types of losses related to natural and man-made disasters? If “yes,” do you have a captive? If self-insurance is partial, how much self-insurance do you have?
9. In a worst-case scenario, how much do you estimate natural and man-made disasters would cost your company after taking into account your insurance and self-insurance provisions?
10. Do you feel comfortable that your current insurance/financial strategy is adequate to handle such a loss?
11. Do you rely on reinsurance or government assistance as part of your risk management strategy?
12. What do you see as key barriers to enhancing the robustness of risk transfer for transportation infrastructure systems? Do you see more barriers on the supply or demand side?

#### Post-Disaster Recovery

13. Have you ever received any government post-disaster funding? If Yes, after which disaster?
14. How much public funding did you receive and for what purposes? How long did it take your organization to receive these funds?
15. How much of the post-disaster cost was covered by insurance? How long did it take your organization to get these insurance payments?
16. How much did you have to cover from your own surplus?
17. Do you expect to receive any government post-disaster funding should you experience a severe disaster in the next 5 years?

#### Measures to Reduce Future Losses

18. What actions have you taken to reduce potential losses and facilitate your recovery from natural and man-made disasters or other severe disruptions? (self-insurance, insurance, reinsurance, government assistance)
19. What actions are you planning to take in the future to reduce potential losses and facilitate your recovery from natural and man-made disasters or other severe disruptions?
20. Have you estimated your probable maximum loss resulting from these events? If yes, how much is it? If yes, have you estimated the likelihood of such an event occurring in a given year?
21. What is your current financial protection and recovery strategy to deal with natural and man-made disasters or other severe disruptions? Has it been discussed with the CEO and Board of Directors? When?

#### View of the risk

22. How does your firm approach/manage the four main types of infrastructure disruptions including natural hazards, manmade hazards (i.e. terrorism and cyber threats), accidents, and infrastructure failures?
23. How effective do you find this approach?
24. What experiences have you had (or almost had) in regard to any of these main risks? How big have the losses been? Were these direct or indirect losses?
25. How do your peers view these risks?
26. What is your view of infrastructure resiliency – what does this mean to you?
27. What, if any, is the current role of network security in your resilience plans?