THE MANAGEMENT AND ADAPTATION OF A LEGACY TRANSIT SYSTEM FOR WEATHER EXTREMES IN THE PHILADELPHIA METROPOLITAN REGION

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ABSTRACT OF THE DISSERTATION

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In recognition of its commitment to commuter safety, The Southeastern Pennsylvania Transportation Authority, a transit agency serving the Philadelphia metropolitan region, implemented a severe weather policy during the 2009 – 2010 winter season unlike any other in its storied history. In so doing, the unprecedented decision to shut down its systems due to heavy snowfalls revealed the agency's reluctance and inability to continue to manage the costs of weather-related damage to its equipment (e.g., buses, rail cars, etc.) and infrastructure (e.g., railroad, bridges, sub-power stations, etc.). Furthermore, it signaled the start of a new era in hazard risk management as well as climate change adaptation for a transit agency whose managers face uncertain financial and environmental futures. This case study recognizes that metropolitan places, their peoples, and their social and economic development are threatened by regular and protracted transit disruptions. Its purpose was to explore the future of extreme weather management and climate change

adaptation for a metropolitan transit agency through the examination of its resource and decision-making challenges, constraints and opportunities.

The study incorporates content analyses, GIS mapping, and semi-structured interviews with executive-level managers employed by the Southeastern Pennsylvania Transportation Authority. Important insights on adaptation planning and policymaking for transit systems in general and the managerial and operational circumstances surrounding extreme weather management for the Southeastern Pennsylvania Transportation Authority in particular. Research results show that: (1) transit systems are underappreciated in adaptation planning and policymaking efforts and (2) adaptation's complexity is revealed through managerial (in)decisions pertaining to organizational philosophy, organizational stressors, transit infrastructure location and condition, and capital resources.

The research findings have important policy implications. They show the need for (1) intentional and more aggressive efforts to integrate state, municipal and transit agency adaptation planning and policymaking efforts; (2) the incorporation of socioeconomic vulnerability assessments into existing hazard risk assessments and climate change adaptation strategies; (3) adaptation plans and policies that are written in appreciation of the historical, institutional, physical, social, economic, political and environmental circumstances in which the agency operates from community to community; (4) safety net policy and practice interventions that address the shortcomings of weather resilience strategies; and (5) public education programs centering on the management and adaptation of transit systems for weather extremes.

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Dedication

To my wife Orien and daughters Madison and Jordyn for their tremendous love and sacrifice.

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Chapter One

Toward an Assessment of Severe Weather Management and Climate Change Adaptation for a U.S. Northeast Transit Agency

1.1 Introduction

In the past few years, since weather extremes have grown in magnitude, severity and frequency across the U.S., issues of hazard safety and climate change adaptation have become more and more prominent among transit agencies nationwide. Extreme weather trends will continue over time scales of decades and centuries according to climate change projections for U.S. regions (USGCRP 2009). As a consequence, transit system disruptions are likely to occur more frequently and to last longer. Yet, despite what available and reliable transit systems represent for transit-dependent populations and what they mean to the economic and social development of metropolitan places, current research provides limited insight into transit agencies' handling of actual and potential weather extremes and their outcomes (Chang et al 2010; Regmi and Hanaoka 2010; Lindgren et al 2009; Guo et al 2007; Keay and Simmonds 2005; Suarez 2005; Call 2005; Khattak and dePalma 1997; Changnon 1996; Rooney 1967). This dissertation seeks to fill an apparent void in the literature by assessing the approaches to extreme weather management and climate change adaptation for a transit agency in the U.S. Northeast.

The outcomes of recent events in the U.S. Northeast underscore the importance of knowing the factors that influence a transit agency's approaches toward managing weather extremes and adapting transit systems of all types (e.g., bus, subway, etc.) to climate change. For

example, Hurricane Irene in 2011 and then "Superstorm" Sandy in 2012 caused unprecedented system shutdowns from Boston to Washington, D.C., and exacted tremendous tolls on subways, bridges, rail lines, power substations. Sandy obliterated transit infrastructure in New York and New Jersey and generated just over $5 billion dollars in system-wide damage costs for New York's Metropolitan Transportation Authority, the Port Authority of New York and New Jersey, and New Jersey Transit. When dealing with Irene, Sandy and other extreme weather events in recent years, transit agencies throughout the U.S. Northeast often lacked the financial means, staff and equipment to make adequate preparations, repair damaged infrastructure and return disrupted systems back to standard on-time performance schedules. As a consequence, days, weeks, and, in some cases, months passed by before systems were fully recovered, as event combinations and their close temporal spacing acted as environmental obstacles to agencies' reclamation efforts. Such conditions amplified place-based exposures and physical and financial impacts, owing to greater agency stress and the inability of managers to fully restore systems before the next event occurred. This, in turn, led to repeated agency losses across the board. More importantly, these chains of events revealed the vulnerability of metropolitan places and their peoples to transit system disruptions resulting from cataclysmic and reverberating impacts from weather extremes.

Ample evidence exists of newly formulated policies for managing weather extremes and movement toward climate change adaptation among U.S. transit agencies as evidenced by the participation of some in the Federal Transit Administration's recently launched Transit

Climate Change Adaptation Assessment Pilot Program.[1] However, little is known about these developments, and even now, transit managers are deciding whether, how, when and where to adapt transit infrastructure and systems to actual and potential weather extremes. Particular problems that transit managers in the U.S. Northeast face include infrastructure that exceeds its design life by thirty years or more; the topographical mixtures of metropolitan landscapes; conflicting urban and suburban development regimes; limited and limiting revenue sources; cultural and political differences across urban and suburban communities; and an incredibly diverse and rapidly growing ridership community. Decision-making within these contexts is likely to yield mixed results across metropolitan places and their peoples. The following broad question frames this dissertation:

1) What is the future of extreme weather management and climate change adaption for a metropolitan-serving transit agency in the U.S. Northeast?

Transit agency managers and the complex issues they face are different in many ways throughout the U.S. Northeast and elsewhere. This dissertation conducts a case study of the Southeastern Pennsylvania Transportation Authority to understand the nuances of extreme weather management and climate change adaptation challenges for a metropolitan transit agency. It argues that an understanding of the agency's challenges will help to increase the success of its weather management and adaptation programs. Case research allows for the evaluation of policies and programs with the purpose of identifying factors

[1] The Federal Transit Administration's 2011 Notice of Request for Applications describes the scope of its pilot program. It reads "The pilots will fund transit agencies or partnerships with transit agencies to assess the vulnerability of transit agency assets and services to climate change hazards such as heat waves and flooding. The pilots will also assess initial adaptation strategies and link these strategies to transit agency organizational structures and activities."

that may help to explain their actual and potential successes or failures (Yin 2003). The Southeastern Pennsylvania Transportation Authority was selected as the case study subject for several reasons. First, agency efforts at handling extreme weather events from snowstorms to hurricanes in recent years have garnered mixed results. Second, the agency was among the first in the U.S. Northeast to publicly announce its adoption of a new policy for severe weather events as a direct result of impacts from heavy and successive snowstorms during the 2009 – 2010 winter season. Third, the word aggressive best describes its work toward mitigating climate hazard risks across each of its transit systems. Fourth, during the exploratory phase of the research project, the agency applied for and later won a grant award from the Federal Transit Administration to participate in climate change adaptation assessment pilot program for mass transit agencies. Fifth, the agency maintains what is called a "legacy system" whose age is a century or more years old. Lastly, the researcher's connections to the Philadelphia metropolitan region as a long-time resident factored strongly into the selection decision.

The dissertation makes two important assumptions. First, transit systems are an integral part of the social and economic development of metropolitan places. Since weather extremes pose significant threats to hazard safety and regional economies, all levels of government should prioritize transit systems in their plans and policies for adaptation. Second, metropolitan places are in a continuous state of flux as a consequence of economic, political, social and environmental change processes. This makes extreme weather management and climate change adaptation complex and complicated procedures for

transit agencies of any size and resource capacity. Therefore, any number of factors may contribute to their failure or success from one year to the next. These key assumptions are tested with the aid of the questions below:

(1) What plans and policies do U.S. states and municipalities have for adapting transportation systems to climate change?
(2) To what extent does climate change adaptation planning and policymaking demonstrate a priority concern for mass transit systems?
(3) How have extreme weather events in recent years affected the Philadelphia metropolitan region and its transportation systems?
(4) What are the managerial and operational circumstances surrounding the Southeastern Pennsylvania Transportation Authority's management of extreme weather?
(5) What are the extreme weather event and adaptation practices of the Southeastern Pennsylvania Transportation Authority?
(6) What challenges do managers at the Southeastern Pennsylvania Transportation Authority's face in handling weather extremes and adaptation?

1.2 Dissertation Map

Chapter 2 reviews available literature on the topic of research. Section 2.2 highlights studies on hazards and transport. Section 2.3 delves into the literature dealing with the topic of transport and climate change. The section is subdivided by viewpoints relating to

climate change mitigation, climate change impacts on transport, and transportation adaptation to climate change. Section 2.4 emphasizes studies for institutional decision-making centering on climate change adaptation. Section 2.5 summarizes my thoughts about the gaps in the literature this study may help in filling. Section 2.6 provides concluding thoughts about the chapters. Section 2.7 outlines the research questions within the context of pre-dissertation activities.

Chapter 3 analyzes U.S. state and municipal climate change planning and policymaking documents for their biases in strategies for transportation systems. Section 3.2 describes the research approach and methodology of the study. Section 3.3 provides a description of the documents utilized in the analysis. Section 3.4 details the content analysis approach. In Section 3.5 reviews the origins of state and municipal climate change adaptation plans employed in the study. Section 3.6 highlights the study's empirical findings from the content analysis. Section 3.7 discusses empirical findings. Section 3.8 concludes the chapter and explains the value of utilizing content analysis for identifying biases in state and municipal climate change planning and policymaking and thoughts about enhancing their designs.

Chapter 4 presents case illustrations of extreme weather events in the Philadelphia metropolitan region. Sections 4.2 through 4.3 describe extreme weather events that occurred in most recent history that impacted the Southeastern Pennsylvania

Transportation Authority and other transit agencies in the U.S. Northeast, including the 2009 – 2010 winter season, Hurricane Irene and Hurricane Sandy. Section 4.4 discusses the case illustrations. Section 4.5 provides concluding chapter remarks.

Chapter 5 characterizes the Southeastern Pennsylvania Transportation Authority. Section 5.2 describes the agency's history and the geographical distribution of its transit systems in Pennsylvania, New Jersey and Delaware states. Section 5.3 profiles the agency's ridership. It describes ridership composition, trends and dependence in the agency's service areas. Section 5.4 illustrates the agency's tools and strategies for ordering and organizing its transit systems during extreme weather events. Section 5.5 discusses the agency's resource challenges and constraints. Sections 5.6 and 5.7 describe the agency's management efforts during the 2009 – 2010 winter season and Hurricane Irene, respectively. Section 5.8 discusses the implications of managing and adapting a legacy transit system for weather extremes. Section 5.9 concludes the chapter.

Chapter 6 presents the findings from interviews with managers employed by the Southeastern Pennsylvania Transportation Authority on the topics of severe weather management and climate change adaptation. Section 6.2 describes the research approach and methodology for revealing factors that account for how the agency's managers dealt with severe weather events. Section 6.3 describes the sources of data used in the research. Section 6.4 presents the types of extreme weather management and adaptation practices

the agency employs. Section 6.5 highlights the challenges associated with those practices. Section 6.6 provides a discussion of the findings. Section 6.7 concludes the chapter.

Chapter 7 concludes the dissertation. Section 7.2 synthesizes the research findings contained in the empirical chapters. Section 7.3 discusses the theoretical implications for transportation adaptation to climate change in urban environments. Section 7.4 outlines policy implications resulting from the research. Section 7.5 discusses the limitations of the study. Section 7.6 identifies future research projects.

Chapter 2

Literature Review

2.1. Introduction

The dissertation draws from literature dealing with hazards and transport, climate change and transport, and institutional decision-making centering on climate change adaptation. Hazards and transport literature engages with issues related to hazard threats and impact loss. It provides unmistakable value toward understanding what is at stake when metropolitan regions are without functioning and available transportation systems. The body of literature dealing with climate change and transport addresses notions of environmental protection and vulnerability. Issues of impact disruption and loss of transportation systems can be gleaned from field studies in this literature base. Because the topic of mass transit adaptation to climate change is not a well-defined area of research in social science fields, general and relevant studies of institutional decision-making supports the effort to help shape it. This literature offers keen insights on a wide range of challenges, constraints and even opportunities for adaptation decision-making that help in building clarity for the problems and issues that mass transit professionals are likely to face.

This chapter is divided into several sections. Section 2.2 discusses the importance and role of transport in managing hazards as well as its potential for producing and amplifying them. Section 2.3 presents literature on climate change and transport, covering such sub-themes

as mitigation, physical impacts, and adaptation. Section 2.4 highlights literature on institutional decision-making on climate change adaptation. Section 2.5 summarizes the reviewed literature. Section 2.6 provides concluding thoughts about the literature review. Section 2.7 outlines exploratory questions that guide the dissertation and its theoretical contributions.

2.2 Hazards and Transport

The hazards and disasters research communities understand the purpose and value of available and functional transport for emergency preparedness, effective response and recovery from extreme events (NHC 2009). Whether it is a neighborhood street, sidewalk, mountain path, highway, railroad, waterway, airway, subway tunnel, rail station, private automobile, hi-speed rail line, bus or ferry, transport in any of its forms is an indispensable lifeline for people and places (Niedzielski and Malecki 2012; Dalziell and Nicholson 2001). Broadly speaking, the absence of transport raises the likelihood for catastrophic human health consequences in extreme event situations like earthquakes, hurricanes and terrorism for it is an urgent and life-saving need for moving people and equipment from places of extreme crises to areas of low risk and vice versa (Günnec and Salman 2011; Horner and Widener 2011; Savonis et al 2008; Wolshon et al 2005(a); Wolshon et al 2005(b); Scanlon 2003; Dow and Cutter 2002; Keller 2002; Dalziell and Nicholson 2001). This makes understanding the decisions of responsible agents for providing well-functioning and available transport resources throughout extreme event cycles of utmost

importance to the planning and practice of mobilizing and distributing them to diverse communities in times of crisis.

Principally, the provision and use of travel resources throughout extreme event cycles are the responsibility of everyday citizens. In the United States, whether they own a private automobile or not, the prevailing view is that citizens possess the ability to gain access to one to avoid harm (AHUA 2006). This mode of thought has been challenged by high-profile incidents related to severe weather and terrorism. Hurricane Katrina and the collapse of the World Trade Center revealed not only the resource limitations of vulnerable populations but also the potential for mass transit to support and achieve planned and unplanned evacuation goals and objectives (Litman 2006; Kendra et al 2003). It is unknown whether transit professionals will overlook their institutional circumstances and interests toward assuming extraordinary responsibility beyond contractual agreements with customers and liability policies structured by insurance companies. Studies that explore the utility of their systems as pressure release valves in hazard management situations press this issue, however. For instance, with the idea that "public transit plays an important role in emergency evacuations," VanLandegen and Chen (2012) integrated a GIS-based network analysis with a microsimulation-based evacuation model to develop large-scale emergency evacuation scenarios for the Pentagon in Washington, DC. Journey-to-Work data from the U.S. Census Bureau and rail system service specifications from the Washington Metropolitan Area Transportation Authority (Metro) were used to characterize transit ridership, evacuation demand, and station locations. Washington, DC's Metro rail transit system was shown to accommodate a large-scale evacuation under the condition that evacuees are managed in a way as to not overburden particular stations and increase

evacuation time. The Pentagon case study does not account for the short- and long-term capital and human resource risks, impacts and costs transit professionals are likely to consider in their decision-making toward dealing with emergency evacuations. Whether the Metro transit agency would be available and able to perform at peak capacity received no consideration as well. Scenario studies such as this show the need to establish a clear understanding of what transit agencies may be able to deliver on the basis of their resource capacities. The topic of resource capacity relating to crisis management is discussed further in Chapters 5 and 6.

Studies of weather-induced transport hazards detail conditions that likely limit mass transit agencies' resource capacities. The physical dimensions of heavy rainfalls and roadway collisions have been characterized by some investigators (Andrey et al 2003; Changnon 1996). Others have detailed the results of street and highway obstructions from heavy snowfall events (Symons and Perry 1979; de Freitas 1975; Rooney 1967). Combined precipitation events and social factors that lead to increased traffic congestion and impassable roadways has been the work of others (Call 2005). Studies of commuters' modal choice decisions (e.g., private automobile, public rail or bus transport, etc.) in variable weather situations have drawn further attention to the production of risk factors resulting from increased travel demand (Guo et al 2007; Keay and Simmonds 2005; Khattak and dePalma 1997). Roadway collisions, high traffic volumes, and street and highway obstructions, and greater consumer demand for over- and under-utilized transport modes can lead often to substantial delays for transit systems.

The transport and hazard literature dealing with weather reveals a number of important insights for this study. Weather is a powerful influence in transforming transport systems into hazards despite their intended designs and uses. Their management during the course of severe weather cycles therefore carries significant risks, challenges, and constraints. Climate change increases the complexity and uncertainty of pre- and post-event management decisions and their outcomes, as it may limit the time and space mass transit professionals need to manage not only normal weather patterns but also surprises encountered during the course of their operations. This emphasizes the need for transit professionals to mobilize resources to maintain a good state of repair due to the deteriorating nature of their systems, particularly in urban environments (Ruth and Coelho 2007).

The literature on weather-induced transport hazards also shows that despite their importance in developing and implementing policy, management and investment decisions for climate change risks and impacts, mass transit officials apparently have been of little concern to researchers. The insight available on hazard risk and event decision-making and management from a mass transit perspective is limited and centers on volcanic ash-induced air travel disruption, which mainly has influenced global travelers (Adey and Anderson 2011; O'Regan 2011). Notwithstanding the importance of knowing how mass transit officials deal with rare geophysical events that inconvenience high-income groups, there still is a rising and pressing need for researchers to explore the nature of their

decision-making in relation to day-to-day disruption and potential loss caused by severe weather and flooding that impact the most vulnerable in society and cause economic disruption in urban and suburban places.

The hazards and transport literature provide the conceptual means to explore mass transit professionals' conceptualizations of severe weather hazards. It is most useful for investigating the values they ascribe to their systems in hazard crisis situations and the factors they consider when making them available to the public or not. Little is known about the decision-making factors mass transit officials take into consideration when coping with and managing severe weather events such as past event experiences, capital and human resources, institutional interdependencies, ridership habits, etc. This dissertation therefore fills a gaping hole in the hazards and transport literature. It draws special attention to the decision-making process as it relates to severe weather management and investments in climate change adaptation. This is done to explore challenges, constraints and sensitivities of a fiscal, institutional, and environmental nature that transit professionals face on a daily basis and which climate change helps to further exacerbate.

2.3 Climate Change and Transport

In general, direct experience with the physical world (e.g., energy consumption, traffic congestion, snowstorms, hurricanes, etc.) drives mass transit agencies and other transport institutions to mitigate their environmental impacts (e.g., pollution) and reduce their

physical exposures or vulnerabilities to severe weather risks and impacts for cost-saving, patron, and worker safety measures. The complex set of cultural, political and economic interactions taking place around them act as critical factors in the efforts toward dealing with environmental change issues as well (Stefanovic 2003). The following subsections' aim is to highlight the relatively sparse literatures on climate change and transport. They are divided into three broad categories: climate change mitigation; climate change impacts on transport; and adapting transport to climate change.

2.3.1 Climate Change Mitigation

Greenhouse gas mitigation is most representative of the scholarship on climate change and transport. Despite the usefulness of mitigation studies in championing campaigns toward reversing environmental feedback trends, they are least relevant to this dissertation's exploratory goals. It must be mentioned here, however, that mitigation helps to bolster and sustain adaptation actions and vice versa. Transport mitigation studies generally provide widely overlapping views on greenhouse gas (GHG) emission-causing agents (Chapman 2007; Wright and Fulton 2005), built environment interventions (Banister 2011; Grazi et al 2008), policy and institutional reform efforts (Marsden and Rye 2010; Berrittella et al 2008), sectoral adjustments and transformations toward decarbonization (Peeters and Dubois 2010; Stanley et al 2009), and consumer awareness of environmental impacts and behavioral choice (Avineri 2012; Dickinson 2010; Hares et al 2010; Line et al 2010). In general, such investigations parallel the environmental justice and transport equity literature that take into purposeful account the human health impacts transport policy,

planning and investments engender that lead to all sorts of pollution burdens for the most vulnerable in society (Bullard 2008; Sen 2008; Sanchez and Brenman 2007; Schweitzer 2006; Schweitzer and Valenzuela 2004; Fietelson 2002; Forkenbrock and Schweitzer 1999). Researchers have cited most recently issues of environmental justice and equity as central to adapting transportation to climate change (Jacobs et al 2011), highlighting critical linkages between place-based transport disadvantage, natural hazard and disaster vulnerability, and socio-economic disparities for particular racial, income and gender groups living and working in and around major urban centers.

2.3.2 Climate Change Impacts on Transport

The physical stability of transportation systems is dramatically influenced by severe weather conditions (Dobney et al 2009; Koetse and Rietveld 2009; Changnon 1996; Thornes 1992). As such, research efforts focus on the extent to which they will be impacted in the future as climate change trends progress. Arkell and Darch (2006) conducted a place-based risk and impact assessment for London's transport network of waterways, roads, subway tunnels and rail stations. In addition to flood risk and vulnerability along the Thames River that threatened roadways, air flow conditions in subterranean transit systems such as the London Underground were shown to worsen in future decades due to projected heat intensity, threatening not only passenger comfort but also respiratory health unless proper ventilation adjustment measures are made by transport officials. Jacobs et al (2008) conducts a risk and vulnerability assessment of New York City's Metropolitan Transportation Authority's systems' vulnerability to flooding resulting from heavy

precipitation events and sea-level rise, and provides an abundance of recommendations for adaptation. Chang et al (2010) examined potential travel disruption in Portland, Oregon in a highly sophisticated way using an integrated impact assessment method that combined a stream channel survey with hydrologic, hydraulic and travel forecast models to determine flooding probability across road and bridge networks. Suarez et al (2005) examined land use, demographic and climatic change factors while measuring transport efficiency under future riverine and coastal flooding conditions for Boston, Massachusetts and found reductions in network service efficiency due to potential loss and damage. Similarly, Kirshen et al (2008) calculated travel and delay times due to changes in transport infrastructure resulting from projected flooding scenarios over the next century. Climate change vulnerability and impact assessments for transportation systems show their actual and potential weaknesses to extreme and not-so-extreme severe weather events and sea-level rise, particularly in urban situations.

2.3.3 Transportation Adaptation to Climate Change

A vital yet understudied topic in the area of transportation and climate change is adaptation. Eisenack et al (2012) analyzes articles from peer-reviewed journals and "grey" literature reports dealing with transport sector adaptation for the purposes of identifying and classifying adaptation actors, their possible inter-relationships, and adaptation methods. Transport, as broadly defined and researched in the study, includes a wide range of actors

and agents such as transportation, water, energy management firms or operators, infrastructure providers, and users such as households and businesses, however. The researchers find that the sources reviewed consistently omit whether and how suggested transport adaptations should be governed and administered. Regmi and Hanaoka (2011) survey a broad population of stakeholders in transport ministries and road agencies in thirty Asian countries to gauge the level of their awareness of climate change-related risks and impacts to critical transport infrastructure. Survey findings suggest gaps in policy and implementation and the need to improve awareness and establish units within agencies that take full responsibility for adaptation planning and implementation. Lindgren et al (2009) interview railway managers for their outlooks on adapting the Swedish railway system to future climate change through policy, design and management mechanisms. Taking into account railway managers' severe weather mitigation policies and practices, research findings suggest they will likely encounter major railway setbacks in the coming decades unless clear connections can be established between present responses and projected climate change. This study is rich in its clear attention to reducing the physical vulnerability of transport systems yet is void of critical insight into institutional as well as societal implications and consequences of decision-making for rail transport users. Essentially, limited insight into the sorts of decisions transport institutions will likely make as a result of climate change impacts reduces the chances for developing adequate and appropriate interventions to reduce their social and economic impacts.

The paucity of academic research on adapting physical and institutional aspects of transport to climate change shows the pressing need to investigate how mass transit professionals make value of their roles and decisions as to whether and how to manage limited internal and external resources toward fulfilling this daunting task. This accounting is furthermore needed because the urban environments in which mass transit professionals work undergo continuous and constant physical, cultural, economic and political change. This review now turns to a broader body of empirical studies dealing with institutional decision-making for climate change adaptation. Findings and insights from these studies can help to inform this project's perspective on climate change adaptation decision-making for the mass transit agency.

2.4 Institutional Decision-making for Climate Change Adaptation

Adger (2000) writes that the concept of adaptation does not have widespread agreement and that institutions are the means through which it is envisioned and managed. For the purposes of this dissertation the term institution is defined as an organization consisting of leaders or officers and the range of human and capital resources they have at their disposal which are secured and utilized for specified social, economic, political or physical objectives for a given time and place. Generally speaking, institutional decision-making involves a set of communicative actions that take place over time through executive board meetings, staff planning meetings, and so forth in which the leaders of the organization and occasionally their subordinates exchange and deliberate over factual and anecdotal evidence to address either a problem or a solution for the purposes of selecting a particular

course of action which is aligned with and benefits the purpose or mission of the institution for the sake of its sustainability.

First-time and reoccurring impacts and losses resulting from extreme climatological events have signaled and are solidifying the need for institutions to design and incorporate adaptation into their policy and management decision-making to better address climate change (Corfee-Morlot et al 2011; Hallegatte and Corfee-Morlot 2011; Adger et al 2005; Adger et al 2003; Fankhauser et al 1999). Adaptation is said to "complement" environmental change initiatives such as mitigation whose aim is to protect Earth's climate sphere from the effects of human-induced greenhouse gas emissions (Harries and Penning-Rowsell 2011; Brody et al 2010). As a concept adaptation varies by contextual meaning, academic field definitions, and its institutional application in physical and social environments (Adger et al 2011; Agrawal 2010; Head 2010; Smit and Wandel 2006). Because governing institutions are primarily mission- and problem-driven they deal with a variety of issues outside of physical environment impacts. Of the many definitions of adaptation that exist today the one that is most useful in conceptualizing the roles they may play toward addressing climate change is proposed by Moser and Eckstrom (2010) who state that:

> Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting nonclimatic changes. Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities (p. 22026).

Climate change decision-making has clear implications and uncertain consequences within and between geographic boundaries (Wilder et al 2010; Leichenko and O'Brien 2008; Rojas Blanco 2006). As a result of this multi-scalar and faceted problem, the wide spectrum of resource-producing and governing institutions in the world are likely to encounter both physical and socio-ecological barriers and constraints toward climate change adaptation. Empirical studies of institutional decision-making dealing with climate change adaptation were thus chosen because of the lack of knowledge that exists for mass transit institutions in this regard. The following studies illustrate the sorts of challenges and obstacles institutions face during the course of deciding what to do about adapting to climate change.

The first grouping of selected studies in this growing body of knowledge seem to indicate that belief systems, historical management frameworks, identities act as primary powerful drivers for inertia and conscious resistance toward climate change adaptation. Adger (2000) identifies combinations of communal and national-level religious, economic and political belief systems and power structures as leading factors in creating flood management risks and impacts and reducing adaptive capacity in Vietnam's Xuan Thuy District through semi-structured interviews with management officials and household surveys. Both state and civil society institutions responsible for the remediation of flood risks were also found to play pivotal roles in further exacerbating collective human vulnerability due to competing environmental perceptions and institutional agendas. These institutions consisted of communes, village councils, local associations, and district-level

irrigation committees. Similarly, Agrawal (2010) emphasizes how historical institutional structures and their network arrangements or the lack thereof hamper adaptation decision-making for new climate regimes among local rural institutions often responsible for managing agriculture, water and other economic sectors. A global-scale comparative statistical analysis of institution, adaptation and livelihood frameworks of local rural institutions accounted for in the United Nations Framework Convention on Climate Change Coping Strategies Database yielded the following findings: (1) civic, public, and private institutions vary in their effectiveness and efficiency in facilitating climate change adaptation; (2) adaptation strategy implementation is driven largely by not only an institution's resource capacity but also its relationship to a particular strategy; and (3) adaptation is largely influenced by the degree to which local institutions filter or block information from external information sources such as state or national forms of governance (Agrawal 2010).Harries et al (2011) and Naess et al (2005) express similar findings of institutional inertia and resistance in their studies of flood risk management. Institutional policy beliefs, practices and cultural legacies serve as powerful drivers of resistance to non-structural approaches to flood risk avoidance even in the face of evident legislative support and action for adaptive floodplain management routines for the Thames floodplain in southeast England (Harries et al 2011). In Norway, centralized governance structures' entrenched fiscal and political investments in structural approaches limit the possibilities of innovative flood management practices among local municipalities that serve as implementation agents (Naess et al 2005). Collectively, Adger (2000), Agrawal (2010), Harries et al (2011) and Naess et al (2005) underscore the importance and role of institutions in both creating and ameliorating climate hazard risk. This suggests that

institutional inertia and resistance may therefore be due in large part by the range of options their stewards perceive to be available to them and whether and how they are being communicated in ways that allow for responsive action.

In general, the second grouping presents adaptation as a novel idea that exists outside of the normal boundaries of coping and response to environmental issues and stress for any institution. On one hand, this makes decision-making concerning the uncertainty and ambiguity that characterize climate change a struggle and difficult task for any institution regardless of its resource capacity, location and scale of implementation. On the other, novel ideas such as full-system shutdowns may serve as catalysts for institutional growth and learning to overcome other pressing administrative matters like budget crises. This is evident in institutional research that examines philosophical frameworks, learning, and individual perceptions of climate change and adaptation.

Dholakia-Lehenbauer and Elliot (2012) suggests that an institution's predisposition to either a constructivist or ecological approach in climate change decision-making determines its policy intentions and use of practical inventions toward avoiding risk judgment errors that result in both institutionally and socially unacceptable consequences. The former approach deals with institutional acceptance of scientific claims of future conditions that result in more immediate action. Today's realities and uncertainty guide incremental movement toward dealing with climate change issues in the latter approach.

Despite which approach or framework an institution knowingly or unknowingly follows, it is the degree to which that institution is willing or bears the capacity to accept accountability that originates from its own adaptation decisions and actions. Accountability may therefore be the ultimate barrier or constraint to institutional adaptation as it carries social, political and economic implications and consequences that operate far outside the range of daily coping and response to "normal" problems.

Berkhout et al (2006) utilizes evolutionary theories of economic change and organizational learning to analyze whether and how well house-building and water utility firms across the United Kingdom learn to adjust and adapt to climate change trends within the scope of their normal routines. Findings from semi-structured interviews and group workshops establish the notion that a firm's basic functions may not easily be adaptable on the basis of its core competencies and business practices. In other words, depending on its orientation and the degree of risk exposure and impact, a firm may find adaptation to be an organizational opportunity for gain rather than a cost for loss due to its level of understanding and acceptance on the part of its managers. This may help explain the (non-) presence of institutions that are adaptation-ready, prioritize it, and achieve some level of relative success at implementing it in comparison to others.

For instance, Jantarasami et al (2010) analyze internal and external perceptions that regional managers and agency staff members of the National Park Service and the United

States Forest Service possess of climate change and adaptation implementation. Internal factors such as unclear instructions or mandates from staff superiors and vague descriptions of job duties and responsibilities were found to impede adaptation progress. Other crucial findings are provided in the researchers' recommendations, including the need to prioritize climate change adaptation; conduct employee training; establish formal labor divisions devoted to climate change issues; and allocate funding for implementation activities. In addition to mitigation, Brody et al (2010) evaluated the degree to which local and state-level public sector agencies across the United States incorporated climate change adaptation into their planning, budgeting and policymaking agendas. It is largely understood that without a "focusing event" such as a natural disaster the likelihood of prioritizing climate change adaptation is low (Berrang-Ford et al 2011). Whether extreme weather events act as the ultimate stressor or tipping point for transformative institutional change that leads to anticipatory rather than reactive decision-making remains an open empirical question (Penning-Rowsell et al 2006). Perceptions of resource availability as well as power and authority not only over decision-making but also direct action are likely drivers of non-committal attitudes and behaviors toward climate change adaptation among institutions.

Lastly, Flugman et al (2012) offers another vision of agenda-setting for climate change adaptation at the individual-scale of analysis through a survey study of the attitudes and behaviors of governmental and non-governmental experts and decision makers toward climate change impacts in the Florida Keys and a proposed Community Adaptation Fund.

They suggest that when faced with resource opportunities and options to implement climate change adaptation, individual willingness to support and participate becomes readily available. It is still unknown whether individual passions lead to institutional agenda-setting, learning, and the development of identity that removes constraints and barriers to climate change adaptation, however.

2.5 Literature Review Summary

Section 2.2 discussed the importance and role of transport in hazards management as well as its potential for producing or amplifying them. Transport was determined to possess both life-saving and life-threatening qualities during hazard crisis event cycles. On one hand, transport helps in shrinking disaster probability and potential when managed efficiently and effectively to create mobility and access to safe places. The opposite holds true given variable circumstances of coordination and extreme conditions on the other as suggested by studies involving climate- and weather-induced transport hazards. There are no known investigations of the factors that contribute to mass transit professionals' decision-making surrounding the provision or termination of travel resources under extreme weather conditions. Furthermore, there are no studies that explore the implications and consequences of their policies and operational strategies for different population groups and places.

Section 2.3 presented literature on climate change and transport. It emphasized transport and mitigation, the physical impacts of climate change on transportation systems, and transportation adaptation to climate change. While not the principal focus of this dissertation, studies of GHG mitigation in the transport sector were presented. Studies dealing with environmental justice and transport equity issues were briefly described as well. The attempt made here was to bridge the gap between mitigation and adaptation, as many mass transit agencies have made greater organizational investments in the former rather than the latter. Whether investments made in climate change adaptation will be or are proportional to the extreme weather impacts and losses transit agencies are encountering now remains to be seen. Also, whether and how mass transit agencies take responsibility to resolve actual and potential conflicts is an open question not covered in extant literature.

Section 2.4 discussed academic literature dealing with institutional decision-making for climate change adaptation. Constraints and barriers to institutional adaptation were shown to originate from cultural belief systems, managerial attachments to historical policy and practice frameworks, resource perceptions, communication inefficiencies, individual attitudes and behaviors toward climate change. With one exception (Naess et al 2005), many of the empirical studies reviewed provide little detail and insight into the day-to-day decision-making processes of institutional managers, particularly under stress whether induced by extreme weather events.

2.6 Concluding Thoughts about the Literature

The need exists for research that emphasizes the human element of transportation adaptation to climate change. In addition to knowing the natural hazards the world's transportation systems face, we also possess a thorough understanding about how and the degree to which extreme weather impacts these systems. Furthermore, we have a detailed understanding of transportation's actual and potential influence on climate change ranging from actual greenhouse gas emissions to policy and built environment interventions. However, we are very much in the dark about the factors that account for transportation managers' handling of extreme weather event and climate change adaptation. The areas of research in need of investigation are expressed as follows:

(1) There is an urgent need for research that investigates the experiences of transit managers and other members within the transportation community in dealing with the management of severe weather events. Little is known about the factors that account for managerial decision-making centering on environmental change and the provision of transportation resources during extreme event cycles. This research goes beyond natural hazard "impact" studies on transportation infrastructure toward deepening our understanding of the range of options managers have at their disposal and use to mitigate climate hazards in urban environments.

(2) Research on transportation adaptation to climate change is in its fetal stage of development. Our insight is limited on the ways in which transit managers and

other transportation professionals plan for and implement adaptations for critical infrastructure (e.g., subway tunnels) and the operation of various transit modes, including bus, rail, trolley, subway, and ferry systems. Further research on implementing adaptation for transit infrastructure and systems is needed.

(3) Mitigation dominates research on climate change and transportation. In addition to its emphasis on transportation's environmental impacts researchers focus strongly on planning and policy, consumer awareness, and built environment interventions. Little attention has been devoted to transportation adaptation to climate change in these areas. There is a pressing need for stakeholder support and financial resources to implement what may be costly and impactful measures. This makes research in areas such as policy and planning research aimed at adaptation a necessity.

This dissertation attempts to address the above gaps in research on hazards and transport, transport and climate change, climate change adaptation, and climate change vulnerability by addressing the above issues.

2.7 Research Questions

The review of the literature revealed a number of gaps in our knowledge about the management of transit systems under extreme weather stress and their adaptation to future

events. This dissertation addresses the importance of understanding and knowing the factors that account for transit managers handling of these issues in urban environments.

The following research questions were developed on the basis of my pre-dissertation fieldwork and reading of the academic literature on hazards and transport, transport and climate change, institutional decision-making on climate change adaptation:

(1) What plans and policies do U.S. states and municipalities have for adapting transportation systems to climate change?
(2) To what extent does climate change adaptation planning and policymaking demonstrate a priority concern for mass transit systems?
(3) How have extreme weather events in recent years affected the Philadelphia metropolitan region and its transportation systems?
(4) What are the managerial and operational circumstances surrounding the Southeastern Pennsylvania Transportation Authority's management of extreme weather?
(5) What are the extreme weather event and adaptation practices of the Southeastern Pennsylvania Transportation Authority?
(6) What challenges do managers at the Southeastern Pennsylvania Transportation Authority's face in handling weather extremes and adaptation?

These questions are reintroduced in the chapters that follow. They help to guide the research toward an assessment of severe weather management and climate change adaptation for the Southeastern Pennsylvania Transportation Authority.

Chapter 3

Transportation Adaptation to Climate Change in the U.S.: A Content Analysis of Planning and Policymaking Documents for U.S. States and Municipalities

3.1 Introduction

Climate change planning and policymaking has taken an intriguing turn in recent years. Not more than a decade ago, greenhouse gas mitigation was the focal point of state and municipal climate change planning and policy agendas for the purpose of reversing global warming trends (Wheeler 2008). The tide in climate change planning and policymaking has since changed to center on adaptation due to the realization that global warming has immediate and severe impact consequences for many economic sectors today, including transportation. This course of action invites an opportunity to explore the visible expression of organized thought concerning transportation adaptation to climate change among U.S. states and municipalities.

This chapter addresses the exploratory questions relating to climate change planning and policymaking for transportation systems in the U.S.. The research questions are:

(1) What plans and policies do U.S. states and municipalities have for adapting transportation systems to climate change?

(2) To what extent does climate change adaptation planning and policymaking demonstrate a priority concern for mass transit systems?

Not all transportation systems and their components (e.g., subways, bridges, railcars, etc.) receive equal levels of attention in adaptation planning and policymaking. Personal and institutional agendas are real obstacles to equality. This is evidenced by federal funding policy which continues to emphasize highway infrastructure and the reduction of greenhouse gas emissions rather than adaptation (Georgetown 2012). The likelihood for adaptation plans and policies to produce fragmented adaptations to occur within and between geographical and spatial boundaries is certain as a result. Thus, equal evaluation of every transportation system to identify key impacts and vulnerabilities is of utmost importance to U.S. states and municipalities. It raises their chances for mitigating impact damage costs, ensuring fewer and shorter disruptions in output across all economic sectors, and safeguarding people's lives and livelihoods during the course of short- and long-term climate extremes.

3.2 Analytical Approach

The approach used in the study to investigate the priorities U.S. states and municipalities attach to adapting transportation systems and their components to climate change is a content analysis of relevant documents over the 2008 – 2012 period. As a research method, content analysis is intended to provide an objective and systematic way of interpreting the content of communication as it appears in visual and audio forms (Berelson 1952). The method employs an organized plan of collecting, assembling, coding, and categorizing content for the purposes of interpreting their meaning. The goal of this content analysis is twofold. First, it is meant to characterize adaptation approaches for transportation systems,

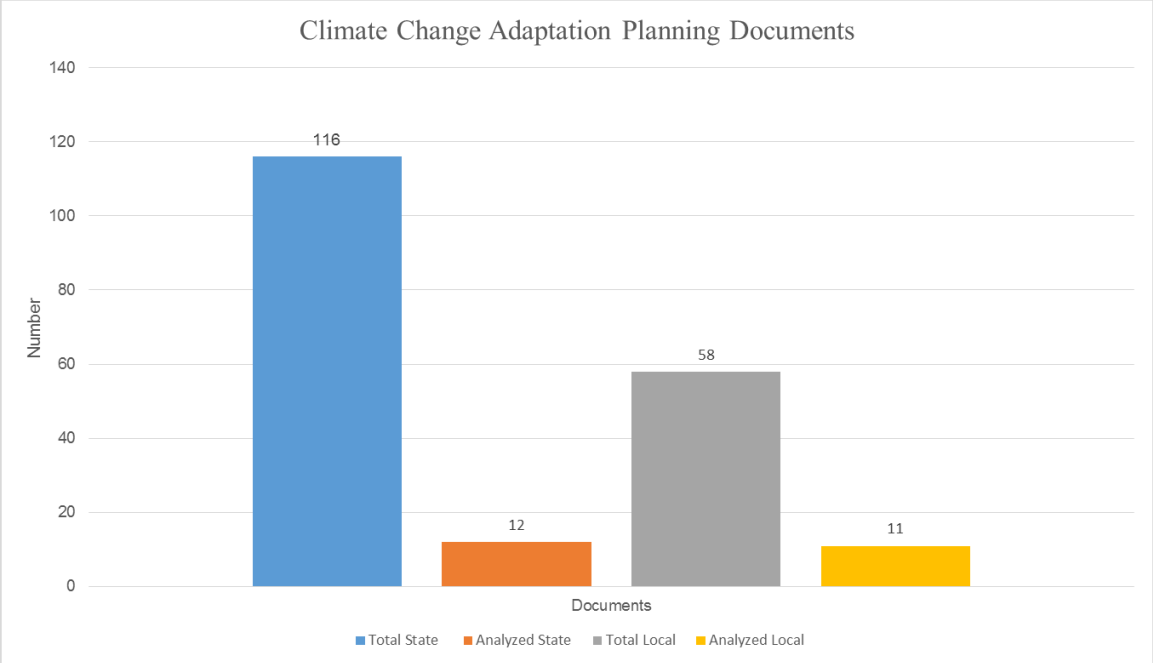
in general. Second, it seeks to identify the priority status collaborators attach to mass transit systems, in particular.

Although the content analysis provides a useful indication of common and uncommon priorities among parties responsible for producing planning and policy documents, noting the limitations of this research method before its findings are interpreted is important. First, each document was produced within different social, political and institutional contexts. Second, as for all jurisdictions, local circumstances generally dictate planning and policy directions. Third, planning and policy intentions do not necessarily constitute implementation so content analysis is ill-equipped to evaluate their progress and performance. Despite the limitations listed, content analysis is an investigative technique that can provide a useful analysis of the importance U.S. states, municipalities, and other stakeholders involved in adaptation planning attach to mass transit systems and their needs.

The following steps were used to proceed with the content analysis of documents. First, documents enlisted for the investigation were collected from the Georgetown Climate Center's online clearinghouse for climate change adaptation plans for state and local governments. The majority of clearinghouse documents centered on climate change mitigation. Documents included in the analysis but not collected from the Center's clearinghouse were identified by the researcher through searches on government agency websites. Second, each document was scanned using keyword filtering software for the

terms transportation, mass transit and public transportation to locate their relevant recommendations, strategies and so forth. Third, relevant data from individual documents was placed into standardized categories. An Excel database spreadsheet was used to organize the data. Fourth, notes for each document were placed into the spreadsheet. Lastly, the database was queried according to the research questions presented. Figure 3.1 shows the number of documents identified and analyzed. The documents used in the content analysis are detailed in the section that follows.

Figure 3.1



3.3 Climate Change Adaptation Planning Documents

Climate change adaptation planning documents for government use address the needs of a variety of economic sectors in dealing with extreme weather events, including public health, agriculture, ecosystem services, energy, transportation, and so on. Often included in the titles of these documents are the terms "strategy," "framework," "recommendations," and "response" in connection with climate change, vulnerability, adaptation, and resilience. In general, these documents are drafted for the purpose of providing government entities (e.g., commissions, agencies, task forces, etc.) with ideas for reducing sector-specific risks and vulnerabilities to climate change.

Climate change adaptation planning documents possess several key elements. In general, they indicate the purpose for their creation via an executive summary and introduction, a listing of working group(s) or collaborators responsible for their assemblage, explanation of the approach used in document development, illustrations of future climate scenarios, demonstrations of sector-specific climate impacts, and short- and long-term guidelines for climate change adaptation. Thus, documents in the investigation typically follow a detailed and neatly organized format. Document formats introduce readers to the overall idea of climate stress on particular geographic areas and their inhabitants, sector-specific climate risks and impacts, the diversity of adaptations, and willingness on the part of the government entity for which the document was prepared to address the challenges contained therein.

The content analysis provides a descriptive profile of adaptation actions regarded as important or feasible for states and municipalities to implement. While the use of a content analysis is appropriate for gathering baseline information on the scope of adaptation planning related to transportation systems across the U.S., it is limited in its ability to assess implementation. Semi-structured interviews with transportation professionals in the study are designed to address this methodological shortcoming. A listing of state and municipal adaptation planning materials used in the content analysis is included in Appendix A.

3.4 Origins of State and Municipal Climate Change Adaptation Plans

State and municipal climate change adaptation planning documents' origins vary. Executive orders by state governors drove the creation of some while legislative bills presented and approved by state-level house and senate assemblies were the political driving forces behind the formation of others. Research centers at higher education institutions are directly responsible for the development of still more. Different combinations of government departments and agencies, research institutes, not-for-profit organizations, private firms, and consulting agencies were responsible for document production processes in all cases.

Executive orders and legislative mandates aided in creating the state and municipal commissions, working groups, and advisory councils and panels from which most plans were conceived and drafted. They have acted as impetus for the creation of similar bodies

at the municipal level in some instances. Tables 3.1 and 3.2 show state-level executive orders and legislation for the establishment of climate change adaptation planning activities.

Table 3.1 Climate Change Executive Orders for U.S. States, 2007 – 2009

State	Executive Order No.	Effective Year
Alaska	238	2007
California	S-13-08	2008
Maryland	01.01.2007.07	2007
Virginia	59	2007
Washington	09-05[2]	2009

Table 3.2 Climate Change Legislative Acts for U.S. States, 2008 – 2010

State	State Legislation No.	Effective Year
Connecticut	Act 08-98	2008
Maine	LD 460	2009
Massachusetts	Chapter 298	2008
Rhode Island	RIGL 23-84	2010
Pennsylvania	Act 70	2008
Washington	SB 5560	2009

California's Executive Order S-13-08 provides an example of the formality of climate change adaptation planning. The order calls for (1) an independent panel to be convened by the National Academy of Sciences to devise its first Sea Level Rise Assessment Report;

[2] Governor Christine Gregorie's 2009 executive order served to "reinforce" the requirement set by State Senate Bill 5560 for all of Washington State's agencies to collaborate with local and federal agencies toward the development of an "integrated climate change response strategy" according to the state's Department of Ecology that published the report titled "Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy."

(2) public assistance in collecting relevant policy information to complete the Report and increase statewide impact awareness; (3) report content parameters and publication completion timeframes; (4) report updates and panel reviews; (5) state agencies to factor sea level rise scenarios into planning construction projects in vulnerable areas; (6) transportation system vulnerability assessments that "include provisions for investment critical to safety, maintenance and operational improvements of the system and economy of the state;" (7) the development of a state Climate Adaptation Strategy; and (8) the centralization of statewide land-use planning guidance on climate change related risks and impacts to be led by the Governor's Office of Planning and Research and California Resources Agency. Adaptation planning for other jurisdictions are less contrived. For Oregon's "Climate Change Adaptation Framework," the governor is said to have simply "asked the directors of several state agencies, universities, research institutions and extension services to develop a climate change adaptation plan" (p. i).

Municipal-centered adaptation planning is led strongly by direct technical assistance from organizations such as the International Council for Local Environmental Initiatives which is also known as ICLEI-Local Governments for Sustainability. The global nonprofit organization was established in 1990 to aid local governments in a range of environmental change initiatives from the measurement of greenhouse gas emissions to the development of climate action plans. ICLEI is a membership-driven organization whose members include city councils, regional planning agencies, and metropolitan planning organizations. Several of the municipal plans analyzed illustrated ICLEI involvement.

3.5 Empirical Findings

Regardless of the sample size undertaking a content analysis is a time consuming process, since each document needs to be carefully examined, categorized and evaluated for overlap. The key empirical findings of the content analysis are reported in this section. They are organized by the geographical distribution of documents, general adaptation categories, and presentation of the priority status afforded to mass transit systems. The reader should note that a degree of overlap exists among the general adaptation categories despite the researcher's ardent attempt to draw their distinctions.

3.5.1 The Geographical Distribution of Documents

Figure 3.2 shows the geographical distribution of climate change adaptation plans analyzed in this study. More than two-thirds of U.S. states are either without plans that deal with climate change adaptation or have yet to make them accessible to the general public. The Northeast and West regions of the U.S. show the highest representation of states with plans. Midwest, South and Gulf Coast states are underrepresented in the content analysis.

Figure 3.2 States with climate change adaptation plans analyzed in this study

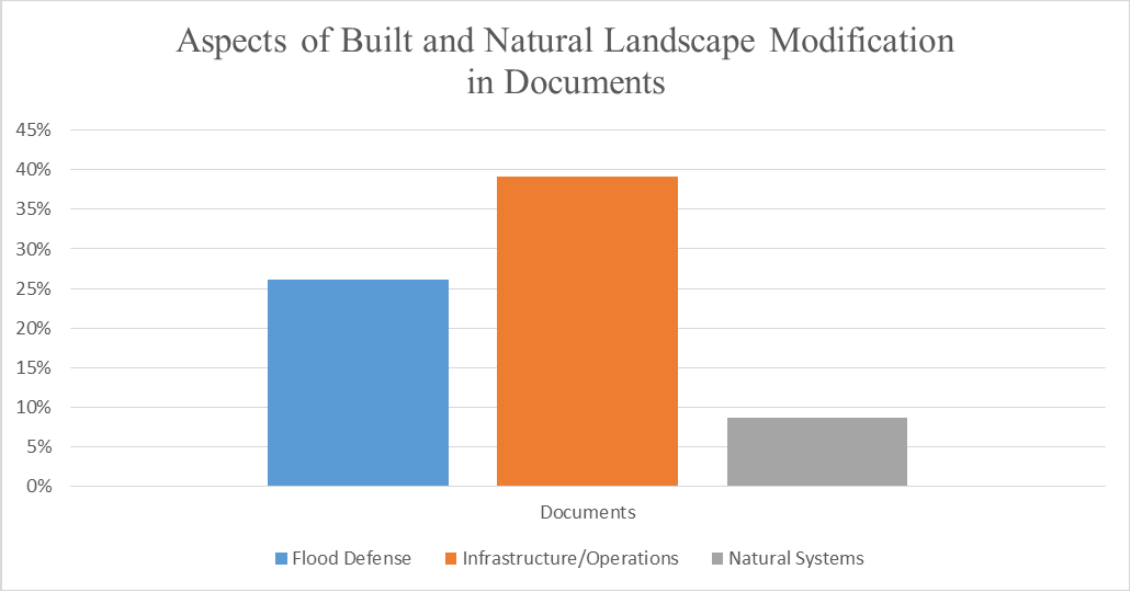
3.6 General Adaptation Categories

3.6.1 Built and Natural Landscape Modification

The modification of built and natural landscapes is a type of adaptation practice. Built and natural landscape modification aspects are divided into three types, namely flood defense, infrastructure and operations, and natural systems. Figure 3.3 shows their level of representation in the planning documents. Flood defense is considered an important strategy among several states and municipalities. Flood defense generally takes the form of the creation or improvement of sea walls or levee systems to protect transportation

facilities located in low-lying flood prone areas and coastal zones from inundation. Specific reference was most often made to protecting airport facilities such as runways from sea level rise and flooding from nearby waterways due to heavy precipitation events. Modifying infrastructure and operations drew the most attention in this category. Infrastructure modifications include abandoning, relocating, retrofitting, or constructing travel assets such as railroads, highways, bridges, and airport runways for vulnerability reduction purposes. Few documents specify actual locations and facilities where these activities need to take place. Bus depots, subway tunnels, hi-speed rail stations and other public transportation infrastructure were not cited in reference to specific adaptations. Natural environment systems received the least attention in this category. Connecticut State's plan deems it necessary to address sedimentation transport issues that adversely influence seaport operations through dredging. Invasive plant species appear to be a problem for transportation systems in Pennsylvania so the state recommends the need for herbicide management for control purposes.

Figure 3.3

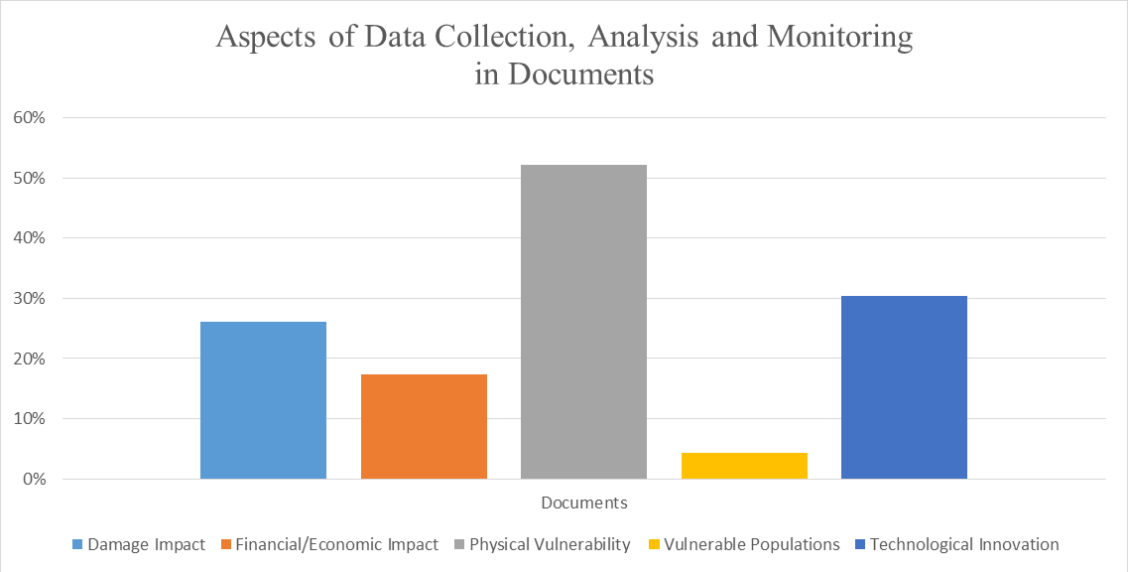


3.6.2 Data Collection, Analysis and Monitoring

Data collection, analysis and monitoring aspects are generally described as the means used by managers to understand and know where and perhaps how to direct their adaptation energies. The representation of data collection, analysis and monitoring recommendations are shown in Figure 3.4. Assessing the physical vulnerability of transportation systems to extreme weather events and climate change trends such as sea-level rise tends to be the most cited of all among reports. Physical vulnerability assessments range from "hot spot mapping" with the aid of sophisticated mapping technologies such as Geographical Information Systems (GIS) to table-top desk exercises wherein the most vulnerable transportation facilities and their locations are discussed among stakeholders in anticipation of impacts from extreme weather events. Damage impact assessments or post-

event assessments is a crucial component of adaptation for only one document. The ability to "speed up" the recovery of transportation routes disrupted by extreme weather events by improving damage assessment capacities is prioritized in Oregon's adaptation plans. A handful of documents draw attention to the acquisition and use of technological innovations that capture and communicate desired weather and impact information. In addition to GIS, documents cite the development of digital databases that will help managers to keep track of built, adapted and impacted transportation infrastructure. They also speak of climate sensors for transportation infrastructure that detect the rate of change in temperature, precipitation, and wind. Such technological innovations are viewed in documents as useful and necessary tools for adaptation. While most documents reference the financial burdens of extreme event recovery costs and economic sector losses, only a handful place focused attention on financial and economic impact assessments. Three states (California, Pennsylvania and Virginia) and one municipality (San Diego, CA) show the importance of such assessments through specific recommendations. The assessment of vulnerable populations garnered the least attention among documents. Only the California State plan communicates the need to incorporate the assessment of the vulnerability of low-income persons in hot spot mapping efforts.

Figure 3.4

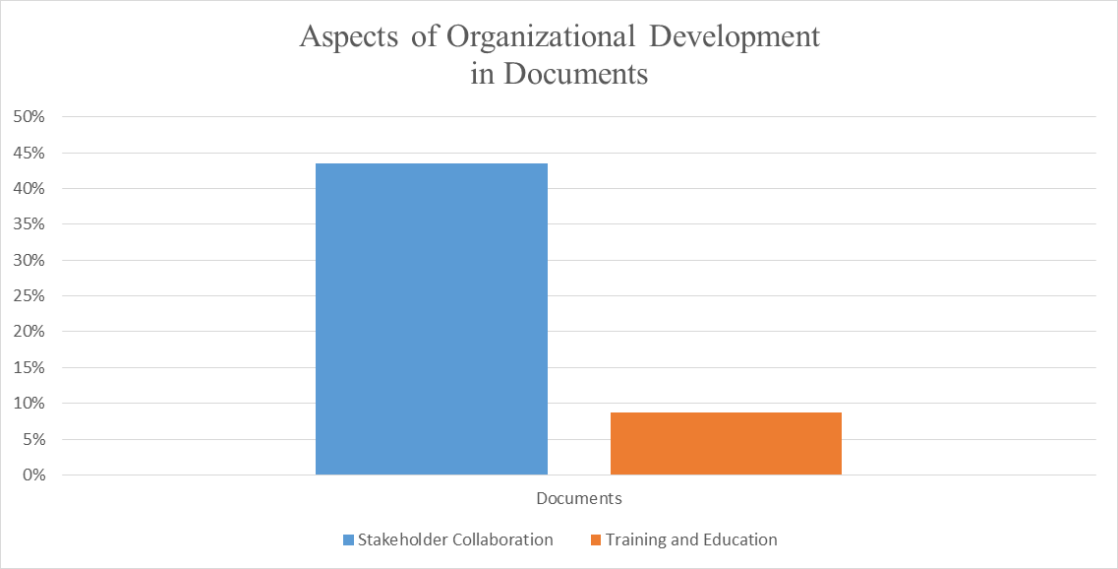


3.6.3 Organizational Development

Organizational development is vital to climate change adaptation. The likelihood that adaptation recommendations or strategies will be implemented without the commitment of different organizational types to work intelligently, proactively and collaboratively is null. Figure 3.5 shows the organizational development focus that documents in the sample display. Stakeholder collaboration dominates the category. Documents generally describe stakeholders as all bodies of U.S. governance, their associated departments and agencies, private firms, research institutions, not-for-profit organizations, and the general public. Specific collaborations between transportation organizations and other stakeholders are often highlighted to communicate actual and potential interdependencies and interrelationships for implementation. Lesser attention is devoted toward training and education. Two plans emphasize their need. While adapting transportation systems to

extreme weather events is not its core intent, Kentucky's adaptation plan recommends that education programs be designed to aid transportation planners and the general public in learning "the importance of corridors for wildlife." New York's plan for mainstreaming adaptation into general management operations recommends that managers employed by the New York State Department of Transportation receive training via webinars or in-classroom instruction in the areas of climate science, future climate scenarios, changing guidelines (for NYSDOT design, construction and operations), climate change planning and adaptation assessments, and monitoring methods for site-specific impacts.

Figure 3.5

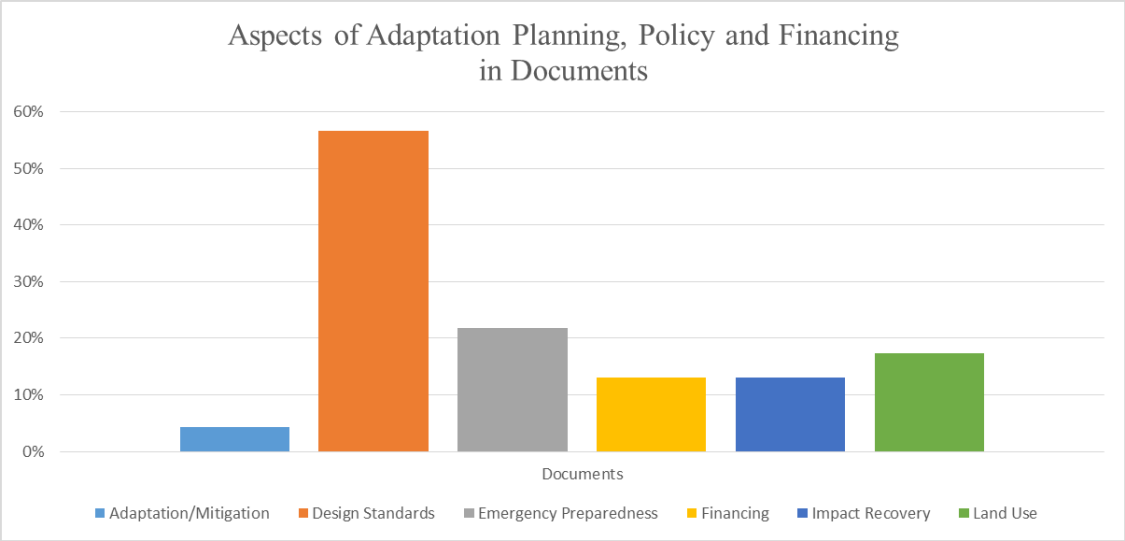


3.6.4 Planning, Policy and Financing

Planning, policy and financing aspects are divided into six types, namely adaptation and mitigation policy integration, design standards, emergency preparedness, funding incentives, impact recovery, and land use as shown in Figure 3.6. Integrated adaptation

and mitigation policies receive very little attention among documents. Such policies are meant to realize their co-benefits. The analysis indicates that design standards for transportation infrastructure are accorded priority attention. Design standards focus primarily on utilizing climate change projections for sea-level rise and flooding from heavy precipitation events in new construction and retrofitting projects for bridges, highways and airport facilities. For Alaska, design standards concentrate on adapting transportation facilities to permafrost thawing. Emergency preparedness has moderate importance. Common to emergency preparedness are the provision of alternative travel operations for evacuations, evacuation planning, and communicating transportation system shutdowns. The need to design and create airport terminal space to house stranded passengers is highlighted in Pennsylvania's plan. Financing lacks high-level significance among documents although most adaptations cannot be implemented without it. A total of two states (Connecticut and Washington) and one municipality (Punta Gorda, FL) consider its importance as an adaptation strategy or response. Land use planning and policies center on such matters as the establishment of buffer zone guidelines and reducing the potential for transportation systems to be built in vulnerable areas.

Figure 3.6



3.7 Prioritizing Mass Transit Systems

Roughly 42% of the documents analyzed make some sort of reference to public transit systems. Despite these references, there are very few instances in which specific recommendations or strategies are connected with them. For states, Connecticut's report indicates the need to develop high-speed rail between New Haven and Springfield as an alternative to its vulnerable shoreline rail route. Washington State suggests the need to guide and reward "local transit organizations" for showing awareness and effort toward reducing transportation system vulnerabilities through regulatory and incentive programs. Incorporating multimodal transportation planning in cost-benefit analyses is an important adaptation task for Wisconsin.

Municipal plans set out fewer steps for adaptation in comparison to state-level plans. Out of the 11 plans, 6 made specific reference to adapting the different components of mass transit systems (e.g. railroads, subways, etc.). Two documents offered specific recommendations or responses to extreme weather and climate change trends such as sea-level rise. The San Francisco Bay Area plan cites retrofitting existing flood defenses as a key adaptation approach to protect Oakland International Airport against sea-level rise and levee failure. Although it uses vague language, the City of Fresno, CA cites the need to use whatever it considers to be public transportation to shuttle vulnerable groups to cooling places on extreme heat days. Although their titles communicate that adaptation is their focus, the remaining municipal plans emphasize the role mass transit plays in reducing greenhouse gas emissions.

3.8 Discussion

The results from the content analysis reveal a number of limitations of current approaches in adaptation planning and policymaking approaches for transportation systems in the U.S. There are a number of reasons for this. First, geographical circumstances establish the level of climate change threat to transportation systems and thereby drive recommended or suggested adaptation approaches. For example, plans often refer to transportation infrastructure at high risk of inundation as a consequence of their hazardous locations in coastal zones and near inland waterways. Mud and rockslides resulting from extreme precipitation events in mountainous places are referenced by a few. Extreme weather events that impacted these locations in recent years demonstrated the need for relocating,

armoring or abandoning privately and publicly-owned transportation infrastructure. However, documents are unclear on when and how such steps are to occur. They also provide little guidance on the adaptation of transportation infrastructure not currently impacted by extreme weather events but whose exposure rates are likely to increase as climate change unfolds.

Second, the practice of assessing the physical vulnerability of built infrastructure such as bridges, highways and tunnels is an evolved and widespread adaptation practice. States and municipalities have been made aware of the physical vulnerabilities of transportation systems with assistance from higher education institutions and environmental change groups such as ICLEI. Physical vulnerability assessments are low cost investments which are intended to yield high rewards. Managers need to know what happens to fixed infrastructure and where it occurs within the context of extreme weather events in order to implement adequate adaptations. People are less predictable. Documents draw less attention to assessing the vulnerability of persons in relationship to transportation system disruptions resulting from extreme weather events. Furthermore, there is no deep or critical attention given to whether adapting transportation systems to climate change will affect different people and places.

Third, despite their social and economic contributions to U.S. states and municipalities mass transit systems (e.g., bus, subways, etc.) are of low importance in analyzed documents

in comparison to state assets such as highways. Local and regional transportation agencies are cited in municipal documents but no specific recommendations for adaptation are attached to them. Most adaptation approaches center on bridges, highways and airports, ranging from retrofit projects to the construction of moving sea walls to reduce flooding incidents. San Diego's Bay Area plan indicates that "the adaptive capacity of local transportation facilities is very low." In general, this suggests the overwhelming challenges associated with them being locked into the physical, social and economic landscapes of most urban environments.

3.9 Conclusion

Today climate change planning and policymaking in the U.S. center on impacts from climate extremes that place physical infrastructure, economic output and the financial status of states and municipalities in jeopardy. This chapter empirically examined relevant content from 23 climate change adaptation planning and policymaking documents for government use during the period 2008 – 2012. The content analysis revealed a number of limitations of adaptation planning and policymaking approaches for transportation systems. The research technique served to determine adaptation approaches for transportation systems in appreciation of the degree to which mass transit systems are prioritized. The primary conclusions and implications from the content analysis are as follows.

First, assessing the physical vulnerability of transportation systems to extreme weather events and climate change trends dominates the current adaptation planning and policymaking landscape. Future efforts need to incorporate the assessment of people's vulnerability to transportation system disruptions resulting from climate extremes and physical and operational adaptations into future planning and policymaking efforts. Second, focused attention on urban environments within state-level adaptation planning and policymaking efforts is lacking. Climate change has uneven impacts so states will need to be flexible in their financing and managerial procedures. Third, there needs to be an intentional focus on adapting mass transit systems to climate change that U.S. states and municipalities publicly recognize as crucial for all geographic scales. Fourth, unlike mitigation plans that have set targets, adaptation documents lack the same level of specificity for implementation. Lastly, accountability is not a hallmark of adaptation planning and policymaking. This leaves adaptation uncertain for targeted transportation systems.

In closing, I would argue that content analysis reveals important insights into adaptation planning and policymaking for transportation systems despite the previously mentioned limitations. Important insights into which adaptation approaches are prioritized and the importance of mass transit systems within planning and policymaking efforts were made possible with this research method. This exploratory research can be complemented with other investigative techniques. For instance, interviews with members of working groups and collaborative teams for transportation-specific adaptation plans and policies can help

to reveal their attitudes, values and beliefs toward different approaches and transportation systems. This idea is partially taken up in Chapter 5 through an examination of semi-structured interviews with managers employed by the Southeastern Pennsylvania Transportation Authority.

Chapter 4

Weather Severity in the Philadelphia Metropolitan Region

4.1 Introduction

Severe weather in the Philadelphia metropolitan region is unpredictable. Rainfall, snow, and high and low degree temperature events are variable, with some years resulting in extreme effects on human health, economies and lifeline infrastructure (e.g., utilities, transportation systems, etc.) whilst others bringing only slight influence. Before discussing the operational and managerial circumstances associated with the Southeastern Pennsylvania Transportation Authority's (SEPTA) handling of weather extremes in Chapter 5, this chapter provides case illustrations of the 2009 – 2010 Winter Season, Hurricane Irene, and Hurricane Sandy to highlight the extent to which extreme weather disrupts people's lives, their livelihoods, and public travel means in the case study area. It addresses the question presented in Chapter 1 that ask:

1) How have extreme weather events in recent years affected the Philadelphia metropolitan region and its transportation systems?

I must note here that this dissertation was inspired by the 2009 – 2010 winter season. While much climate change science and policy centers on extreme rainfall and temperature events, it was this particular winter season which marked the first time in SEPTA's history that officials decided to suspend all transit services as a result of heavy snowfalls (Gammage 2010). Prior to this time the agency ran its systems until snowfall conditions forced them to halt. Hurricane Irene came a year later to show the high vulnerability of

the agency's systems to extreme precipitation events. This storm revealed not only the weaknesses of the agency's severe weather management practices but also the types of human health and safety impacts the region's communities face from system losses. The subsections that follow detail meteorological conditions of the selected events, their influences on natural systems, and human and built environment impacts. Multiple media sources were used in the reconstruction of these significant and impactful meteorological moments which urban and suburban communities across the Philadelphia metropolitan region and elsewhere encountered.

4.2 The 2009 – 2010 Winter Season

The latent vulnerability of mass transit systems in the Philadelphia metropolitan area to severe weather events is well illustrated by the 2009 – 2010 winter season. The area encountered successive and record-breaking snowfalls that later resulted in widespread economic impacts, including transit fare revenue losses and increased transport system and vehicle repairs. On the 19th and 20th of December in 2009, a Nor'easter with significant precipitation volume which originated in the Gulf of Mexico met a cold front in the U.S. north to form heavy snows which would blanket the region with more than 20 inches over the two-day period in some places. The National Weather Service reported that the City of Philadelphia recorded its second highest snowfall total at 23.2 inches after the winter storm had dissipated (NWS n.d.). The highest recorded snowfall for the city occurred on January 7, 1996 with 27.6 inches. For the city's surrounding counties in Pennsylvania snowfall amounts measured from 12 to 23 inches. Counties in Delaware averaged 12 to

20 inches of snow. Similar meteorological results were experienced by counties in southern New Jersey. Snowfall rates of 2 to 3 inches per hour and forceful winds combined to create blinding whiteout conditions across many parts of the region.

Snowfall on the 26th and 27th of December packed a less impactful wallop for densely populated areas with accumulations ranging from 2 – 14 inches for Philadelphia and its surrounding counties in Pennsylvania. Observation reports for southern New Jersey communities indicated that up to 26 inches of snow had fallen in shoreline areas. Inland communities registered between 16 and 20 inches in total. Counties in Delaware recorded a high of 11.7 inches. Light snow accumulations were recorded for the January 30th snowstorm. The highest recorded total was for 11.3 inches. The February 5th and 6th winter storm brought snows of up to 30 inches in the region. Philadelphia recorded 28.5 inches of snowfall precipitation and broke the record it had established just two months before. More snows fell three days later on the 9th and 10th of February with the highest recorded snowfall of 26.8 inches in Pennsylvania's Chester County. The snowfall events of February 25th and 26th capped the season. Accumulations of up to 26.5 inches were observed in the region. Philadelphia and its in-close suburbs registered totals between 5 and 13.5 inches.

Collectively, these storms received the tag of "historic" for their succession and record-breaking snow accumulations in many areas of the region but not for their built environment impacts which had been minimal at the time of their arrival. For the

Nor'easter of December 19th and 20th, natural system impacts were felt closer along the eastern shoreline (NOAA 2010). The storms' threats to economic sectors which rely heavily on direct contact with customers draw exception, however. For bricks-and-mortar retailers, the storm's projected arrival on the final weekend before Christmas signaled potential losses of $1 billion or more because the U.S. northeast region contains the largest market share of traditional storefront shoppers (Dodes and Zimmerman 2009). Many communities across the region experienced power outages during several of the storms. The combination of successive snowfall events and their accumulations likely impacted retailers throughout the season and beyond as many may have made attempts to claim lost revenues through insurance claims and sales promotions which would have cut their profit margins considerably.

Reported snow forecasts of 20 or more inches around the Philadelphia metropolitan region resulted in the disruption of transit service on occasion throughout the 2009 – 2010 winter season. Inter-city transit companies such as Amtrak and Greyhound cancelled service throughout the region. Regional airports cancelled flights. SEPTA followed similar protocols and suspended its service until road and railways were all cleared. Since accumulations occurred rapidly in many parts of the region in some instances agency vehicles already en route to their destinations became snowbound and damaged by snow intrusion. Consequently, the revenue losses mass transit agencies encountered as a result of the 2009 – 2010 winter season came in the form of maintenance costs stemming from damaged facilities due to salting (SEPTA Interviewee 2011), broken vehicles from snow

intrusion, employee overtime for snow and ice removal, contractors, and lost fares. Due to the agency's newly implemented severe weather policy its rail system was able to be returned to normal operating schedules in less than a day's time by managers' claims. As a result of snow-clogged streets which needed to be cleared by municipality street maintenance crews, the agency was less successful in achieving the same for its bus system. In some places, bus routes were either closed entirely or detoured for up to a week or more in some cases until neighborhood streets were entirely cleared of snow by municipal snow removal crews.

The following case illustration of Hurricane Irene shows much greater, wider spread and more immediate human health and safety impacts that result from climate change-trends such as extreme precipitation events. Snow storm events are understood by the researcher to be no less impactful than extreme precipitation and flood events in some instances. Snow storms are less dramatic in immediate impact in comparison to extreme precipitation and flooding events. However, they are no less destructive. Generally, their impacts show up later in time. This is evidenced by erosion damage that appears in infrastructure due to salting and other snow and ice removal efforts weeks and months after the event.

4.3 2011 Hurricane Irene

In 2011, at August's end, Hurricane Irene made contact with urban and suburban communities across the Philadelphia metropolitan region. Forming off the east coast of

the Leeward Islands, the northern collection of islands of the Lesser Antilles in the West Indies, this tropical cyclone system contained and carried extreme winds and heavy rains which influenced the disruption and loss of critical infrastructure and human lives throughout many communities across the region. Official meteorological reports indicate that Hurricane Irene averaged peak wind gusts of up to 50 mph in the City of Philadelphia and its surrounding suburbs (NOAA n.d.). In New Jersey's southern counties, wind velocities reached over 70 mph. Speeds of approximately 66 mph were clocked in Delaware State counties. New precipitation records were set across some parts of the region. For a highlight example, the August record for precipitation was broken in Philadelphia as a result of the 19.31 inches of rainfall that Hurricane Irene delivered to the city over the course of her stay.

Hurricane Irene's heavy rains and extreme winds significantly influenced the region's natural systems. The region's major rivers and minor waterways succumbed within two days' time to severe precipitation. Between the 27th and 28th of August, the Schuylkill River was on par with and also surpassed historical crest heights due to rainfall according to the City of Philadelphia's Mayor, Michael Nutter (Araiza 2011). Extreme and moderate cresting of the Schuylkill and Delaware rivers caused many streams and creeks which flowed through natural and built-up environments to rise above their flood stage heights. The Wissahickon Creek, for instance, a tributary of the Schuylkill which courses through Montgomery and Philadelphia counties in Pennsylvania, rose 5 feet above its established crest height of 5 feet (NOAA n.d.). In New Jersey's Mercer County, the Assunpink Creek,

a tributary of the Delaware River, rose above 7 feet of its flood stage height (Karas 2011). Hurricane Irene's heavy winds wreaked havoc on trees in many communities across the Philadelphia metropolitan region. In Philadelphia, over 400 trees were reported to have been toppled by the likely combination of weakened root systems due to inundation and wind gust conditions (Ghosh 2011).

Changes to the Philadelphia metropolitan region's natural systems from Hurricane Irene's meteorological effects resulted in damage costs of approximately $1.1 billion and a variety of human health and safety impacts (Associated Press 2012). For Pennsylvania, New Jersey and Delaware storm-related fatalities from fallen trees and flooding totaled 14. Widespread and prolonged power outages were the consequence of similar hazard incidents. Utility companies operating in the region reported power outages which influenced over two million or more residential and business consumers for greater than a week in some instances (PAPUC 2012; Delmarva Power 2011; NJBPU 2011). As a measure of hazard safety and security the power output from nuclear facilities were reduced by plant managers (NOAA 2011). Buildings throughout the region collapsed from torrential downpours and high winds. Delaware's Sussex County encountered the loss of approximately 50 structures (Ghosh 2011). In the City of Philadelphia Hurricane Irene's pounding winds and rains caused 7 buildings to collapse (Bloomberg 2011). The storm's meteorological impacts were also felt keenly by the region's highly interconnected transit systems.

With meteorological forecasts that signaled the threat of sustained high winds and extreme flooding from Hurricane Irene (Avila and Cangialosi 2011), transit agencies providing inter- and intra-city service and state transportation departments shut down their systems to avoid human catastrophe (CNN 2011; USDOC and NOAA 2011). Shut downs, however, did not curb hurricane impacts resulting from damaged infrastructure and vehicles and the loss of fare revenues. Reports estimate that Hurricane Irene caused 11,800 flight cancellations which affected 650,000 air travelers along the eastern seaboard. State highways and railways suffered substantial damage from inundation and flash flooding which resulted in widespread road closures and bridge washouts in some areas. Fallen trees made many more impassable in neighborhoods and business centers. In some places, transport infrastructure was returned to functioning status in less than a couple of days. Other places encountered loss and disruption for more than a week's time. For many communities the loss of transit systems led to varying degrees of physical and social isolation during the course of Hurricane Irene's stay and in the following weeks of recovery from her effects.

Hurricane Irene marked the first time in the history of the Southeastern Pennsylvania Transportation Authority that it suspended service for each of its systems, including bus, rail, trolley and subway. However, this act did not curtail damage to its track infrastructure along several lines and the complete loss of power substations which resulted from extensive flooding. Rail lines encountered delays and occasional disruptions for days and weeks in some cases. It also did little to protect several agency rail stations and a dozen

rail cars it had stationed at the Trenton Transit Center from inundation. Detail of the Southeastern Pennsylvania Transportation Authority's handling of Hurricane Irene is provided in Chapter 5.

4.4 2012 Hurricane Sandy

Hurricane Sandy established new hurricane storm activity and impact records in the U.S. After originating in the southwest Caribbean on October 22, 2012 as a tropical depression, Sandy grew to epic-sized proportions to become the largest Atlantic hurricane ever to be documented with winds spreading 1,100 miles in diameter across the South, Mid-Atlantic, Northeast and Midwestern regions. Scientists characterized the hurricane as "peculiar," noting its storm track had an average probability of occurring once in every 700 years (Hall and Sobel 2013). The storm's greatest wind velocity was clocked at 139 mph at Mt. Washington, N.H., giving it a Category 3 rating on the Saffir-Simpson Hurricane Scale during its course (Dolce et al 2012). Its highest storm surge height of 32.5 feet (9.9 meters) in New York Harbor surpassed the previous record height of 25 feet (7.6 meters) set by Hurricane Irene a year before (Duke 2012). Several U.S. cities registered record-breaking daily rainfall totals, including Washington, DC, Philadelphia, Atlantic City, and Wilmington, DE (Greiser 2012). As Sandy merged with an Arctic cold front to become a hybrid storm, this weather system dumped heavy snows in Maryland, North Carolina, Pennsylvania, Tennessee and West Virginia as a consequence. Snow accumulations of up to 3 and 5 feet in some places were reported as "prominent" by meteorologists, since this "unusual" event occurred during the middle of autumn. Damage costs estimated at $68

billion placed Sandy on the list of costliest Atlantic hurricanes behind Hurricane Katrina ($125 billion). Undoubtedly, this ranking shows Sandy's significance in the meteorological record books and its impact on a broad range of communities within several U.S. regions.

Sandy's impacts on human lives and critical infrastructure are best described as sharp and persistent. The storm's real-time wind and rainfall effects were directly responsible for 72 deaths across 8 U.S. states according to impact status reports. Post-Sandy deaths totaled 87. Protracted power outages (hypothermia and nighttime slips and falls), alternative energy sources (carbon monoxide poisoning from back-up generators), and car and tree-removal accidents were linked to post-Sandy deaths. Although damage to critical infrastructure was spread far and wide across impacted U.S. regions, New Jersey and New York bore Sandy's brunt as a result of its storm track. Both states reported unprecedented damage. Southeastern Pennsylvania, where the bulk of SEPTA's transit systems are located, encountered lesser damage by comparison.

In Pennsylvania, about a million customers lost power for a week or more due to downed wires from collapsed trees. Power outages affected 38,000 persons in Southeastern Pennsylvania. There was extensive creek and river flooding throughout the area. In Philadelphia, the Red Cross opened shelters in some places as a result of power outages. There was moderate damage to properties from Sandy's winds and flooding. Full-length

interstate highway closures were mandated by the state's governor due to the flooding. News reports indicate that SEPTA sustained "considerable damage" from Hurricane Sandy along its regional rail routes in areas susceptible to severe winds and rainfall (Wanek – Libman 2012). The agency lost energy transmission lines across several track lines, including Lansdale – Doylestown, Chestnut Hill West and Warminster lines. Its Route 101 Media Trolley Line was also impacted by the storm. The agency reported losses of approximately $550,000 to clear away debris, repair damage, and restore normal service (Jacobs 2012). Other transit agencies in the region were not so fortunate.

Despite implementing service suspensions and other risk and liability-reduction measures such as moving vehicle and clean-up equipment to higher and protected grounds New York City's MTA, the PANYNJ, and NJTransit suffered the highest degree of weather stress and damage among public transportation agencies within all impacted regions (CNN 2013). Collectively, their damage losses were an estimated $7 billion. The mobility of 40 percent of the nation's public transportation users was strained for weeks and months in some cases due to the level of Sandy's impact on networked infrastructure (e.g., tracks, bridges, and tunnels) and equipment (e.g., trains) (Hinds 2012). In New York, subway tunnels and stations in Manhattan, Brooklyn and Queens were shut down for weeks or more for flood removal and critical infrastructure repairs. Service for the Long Island Rail Road and Metro-North Railroad was suspended system-wide as a result of the storm's flood impacts. Subway and regional rail commuters needed to seek and acquire alternative, less convenient and perhaps more expensive options to travel to work, school, etc. as a result

of Sandy's devastation (Kaufman et al 2012). Sandy's most notable impact on rail ridership was in Rockaway, Queens, a coastal peninsula with a mixed population of low, middle, and upper-class residents. Sandy's storm surge destabilized the rail line embankment and flooded the tracks between Howard Beach and Rockaway. This loss in public rail service left a reported 35,000 Rockaway commuters stranded for weeks until the MTA was able to activate free yet limited shuttle service (MTA 2013).

Public transportation infrastructure in New Jersey was devastated by Sandy in equal measure to New York. The Hoboken Terminal, a critical commuter transfer node for PATH and NJTransit trains and buses, received 500 million gallons of hurricane flood waters according to reports and characterized as a "crisis" by the Mayor of Hoboken (Flegenheimer 2012). NJTransit's North Jersey Coast and Atlantic City rail lines were washed out. Several other lines experienced the same fate. NJTransit's Rail Operations Center at The Meadowlands was submerged 8 feet underwater in The Meadowlands. Backup power supply systems, the emergency generator, and train movement systems failed as a direct result of inundation. Downed trees added to the woes of NJTransit officials, as they damaged miles of catenary lines and signal wires across New Jersey's rail transportation system. In a show of camaraderie, SEPTA loaned NJTransit 31 buses from its fleet to fill the gap in rail service between New Jersey and New York City that Sandy helped to produce (Redfern n.d.).

4.5 Discussion

The purpose of this chapter was to illustrate severe weather events and their impacts on the Philadelphia metropolitan region and select parts of the U.S. Northeast on communities, in general, and transit systems, in particular. It provides support in contextualizing interviews with managers employed by SEPTA. Chapter 6 provides interview details. Transit agencies in New York and New Jersey were given attention to show the magnitude of severe weather events. Their transit systems are often used by commuters from the Philadelphia metropolitan region for the purposes of work, shopping, education and so on. The case illustrations presented showed how severe weather events produced different impacts from one event to the next and impact severity from one year to another on the basis of their makeup. This is an important note, since transit agencies have the tendency to use past experience to prepare for future weather events. The most important points of the chapter are as follows.

Severe weather events such as heavy snowfalls show the particular weaknesses of transit systems sometimes weeks and even months after occurring. For example, during the 2009 – 2010 winter season, snow intrusion put rail cars and buses out of commission due to the damage that moisture inflicted upon their engines. The combination of freeze-thaw periods and salting for ice and snow removal resulted in erosion damage of rail station platforms. It would seem that fewer vehicles might exert greater stress and pressure on transit systems that are stretched to and beyond their operations capacity. Reductions in vehicle equipment are likely to amplify hazard risks in crisis situations. Also, severe weather

events have haunting effects. The idea that strategies deemed appropriate to address climate extremes in one year can lead to undesirable effects in another must be unsettling to transit managers, as they produce short- as well as long-term impacts on their limited capital and human resources.

The destructive force of today's severe weather patterns thwarts transit agencies' best efforts at ensuring system resilience. For example, SEPTA'S rightful decision to suspend service for each of its transit systems in preparation of Hurricane Irene provided minor protection for what some may consider the agency's most sacred asset, the railroad. Extensive damage occurred to tracks, rail stations were unusable, and vehicles were lost as a result of severe flooding from the storm for days and weeks at a time. More catastrophic results were produced by Hurricane Sandy for transit agencies serving New York and New Jersey. If such outcomes are to be avoided in the future, then considerable capital and human resources are needed toward adapting heavily exposed infrastructure to climate change projections.

4.6 Conclusion

Case illustrations provide a way for describing and characterizing the impacts of severe weather events on a metropolitan region and its transit systems. Using an array of media sources, from meteorological and impact damage reports from NOAA and public utility companies to newspaper articles, this chapter illustrated the impacts of three extreme

weather events that affected the Philadelphia metropolitan region and elsewhere in recent years, heavy and successive snowfalls during the 2009 – 2010 winter season, Hurricane Irene in 2011, and Hurricane Sandy in 2012. The physical properties of each event and their impacts on human settlements with special attention to transit systems were presented. The chapter then summarized the researcher's thoughts about how severe weather events may influence hazard risks for transit agencies and the need for capital and human resources for the adaptation of highly vulnerable transit infrastructure. The study now turns to Chapter 5 which profiles SEPTA, how it has specifically dealt weather extremes in recent years, and its steps toward climate change adaptation.

Chapter 5

The Southeastern Pennsylvania Transportation Authority and Weather

5.1 Introduction

There are 7,088 transit organizations in the U.S. serving urban and rural areas at the moment (APTA 2012). Just as they vary in organizational composition from small non-profits to large public-private agencies, so too do their services which range from single-vehicle special demand operations for the elderly and disabled persons to multi-modal systems for diverse metropolitan populations. Consequently, their histories, growth and development, capital resources, operational circumstances, and the ways in which they cope with weather extremes and adapt to climate change are uniquely different. As such, a case study of the Southeastern Pennsylvania Transportation Authority (SEPTA) aims to reveal nuances associated with extreme weather management and climate change adaptation for a transit organization that serves a diverse and large urban population. This chapter presents an overview of the agency and its recent dealings with extreme weather events and operational adaptations while addressing the following research question introduced in Chapter 1:

(1) What are the managerial and operational circumstances surrounding the Southeastern Pennsylvania Transportation Authority's management of extreme weather?

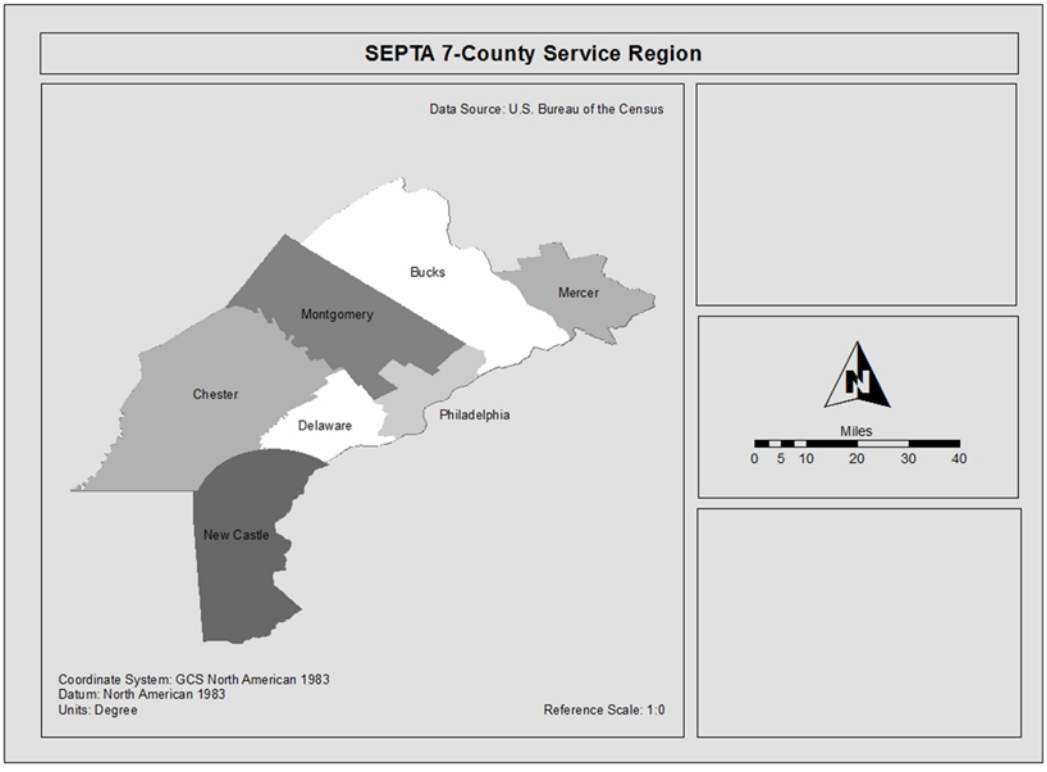
The chapter has several aims. First, it provides the agency's brief history and geography of transit services to show its operational scale. Second, SEPTA's ridership is described to show the different groups that depend on the agency's services and to illustrate their growing dependence on its various systems. Third, severe weather management tools and strategies the agency has formulated in recent years are presented. Fourth, the agency's capital assets within the context of extreme weather events are discussed to highlight the resource constraints and challenges it faces toward future events. Fifth, the impacts of heavy precipitation and snowfall events on the agency's systems and the ways in which it has responded to them are highlighted to contextualize interviews with officials that the following chapter analyzes.

5.2 The Southeastern Pennsylvania Transportation Authority

The Southeastern Pennsylvania Transportation Authority (SEPTA) is the Philadelphia metropolitan region's leading mass transit agency. The Port Authority Transportation Corporation (PATCO), New Jersey Transit Corporation (NJTransit), and National Railroad Passenger Corporation (Amtrak) also serve the region but their daily, annual ridership levels, and area of regional boundary coverage within it are comparatively lower. In 1963, by order or the Commonwealth of Pennsylvania, SEPTA was established to continue and ensure the provision of public railroad service which failed transportation companies such as the Pennsylvania Railroad Company and Reading Company could no longer provide. The acquisition of bus and rapid transit routes (e.g., Broad Street Subway and Market – Frankford Elevated Line) occurred during the late 1960s and early 1970s as a result of the

collapse of the Philadelphia Transportation Company and Philadelphia Suburban Transportation Company. This enabled the agency to establish bus and rail service connections beyond and across the Philadelphia metropolitan region, including the counties of Bucks, Chester, Delaware, Montgomery and Philadelphia in Pennsylvania, Mercer County in New Jersey and New Castle County in Delaware as shown in Figure 5.1. SEPTA's "legacy system" stretches across different "community types," including urban centers, stable working communities, established towns, middle-class suburbs, and affluent suburbs (Adams et al 2008).

Figure 5.1 SEPTA 7-County Service Region



SEPTA is headquartered in the City of Philadelphia. Today the agency ranks sixth among the fifty largest transit agencies in the United States in unlinked passenger trips, and tenth overall in passenger miles driven (APTA 2011). According to the Federal Transit Administration's National Transit Database (2010), the agency operates virtually every mass transit mode, including a combined fleet of approximately 1,985 motor buses, subway and elevated rapid transit trains, rail and trackless trolleys, ADA and shared-ride vehicles, and regional commuter trains. The agency provides travel service to approximately 3.3 million riders over 196 fixed routes and across 869 square miles.

5.3 SEPTA Ridership

5.3.1 Ridership Composition

SEPTA's Fiscal Year 2010 Operating Budget Report (2010) provides figures for what it describes as its "typical" ridership base. They were compiled from its 2008 Customer Satisfaction Survey as shown in Figure 5.1. The table illustrates that more than two-thirds or 64 percent of its passengers are women. Men represent 36 percent of the agency's total passenger population. Nearly a third of the ridership base is between the ages of 18 and 34 at 31 percent. Persons between the ages 35 and 54 represent the largest proportion of riders at 42 percent. They are followed by passengers between the ages of 55 to 64 and 65 and above at 16 and 12 percent, respectively. Passengers whose household income is less than $35,000 are 44 percent of the ridership. Ridership by race shows that African Americans represent the largest proportion at 51 percent. Caucasians or Whites account for 41 percent

of the ridership base. Hispanics and Asians show the lowest rates of transit service use at 3 and 2 percent, respectively. Geographic difference in transit system use among races is also shown. City transit systems are primarily used by African Americans at 57 percent while Whites constitute the largest proportion of passengers that use suburban transit systems at 54 percent.

Table 5.1

Demographic Profile of SEPTA Passengers

	City Bus and Rail Transit	Suburban Bus and Rail Transit	Regional Railroad	Total SEPTA*
Gender (Percent):				
Male	36.5	37.8	39.0	35.8
Female	63.5	62.2	61.0	64.2
Age (Percent):				
18-34	31.6	31.4	30.2	30.5
35-54	41.8	39.9	42.4	41.5
55-64	15.7	17.1	19.0	16.3
65 or older	10.9	11.6	8.4	11.7
Household Income (Percent):				
Less than $35,000	49.5	32.9	20.6	43.9
$35,000 or more	50.5	67.1	79.4	56.1
Ethnicity (Percent):				
African American	56.7	37.4	34.6	50.6
Asian	1.6	2.3	2.3	1.8
Caucasian	34.8	54.1	59.4	41.4
Hispanic	3.6	2.3	1.4	3.1
Other (All Not Listed)	3.3	3.9	2.3	3.1

*Weighted Average

Source: 2008 SEPTA Customer Satisfaction Survey

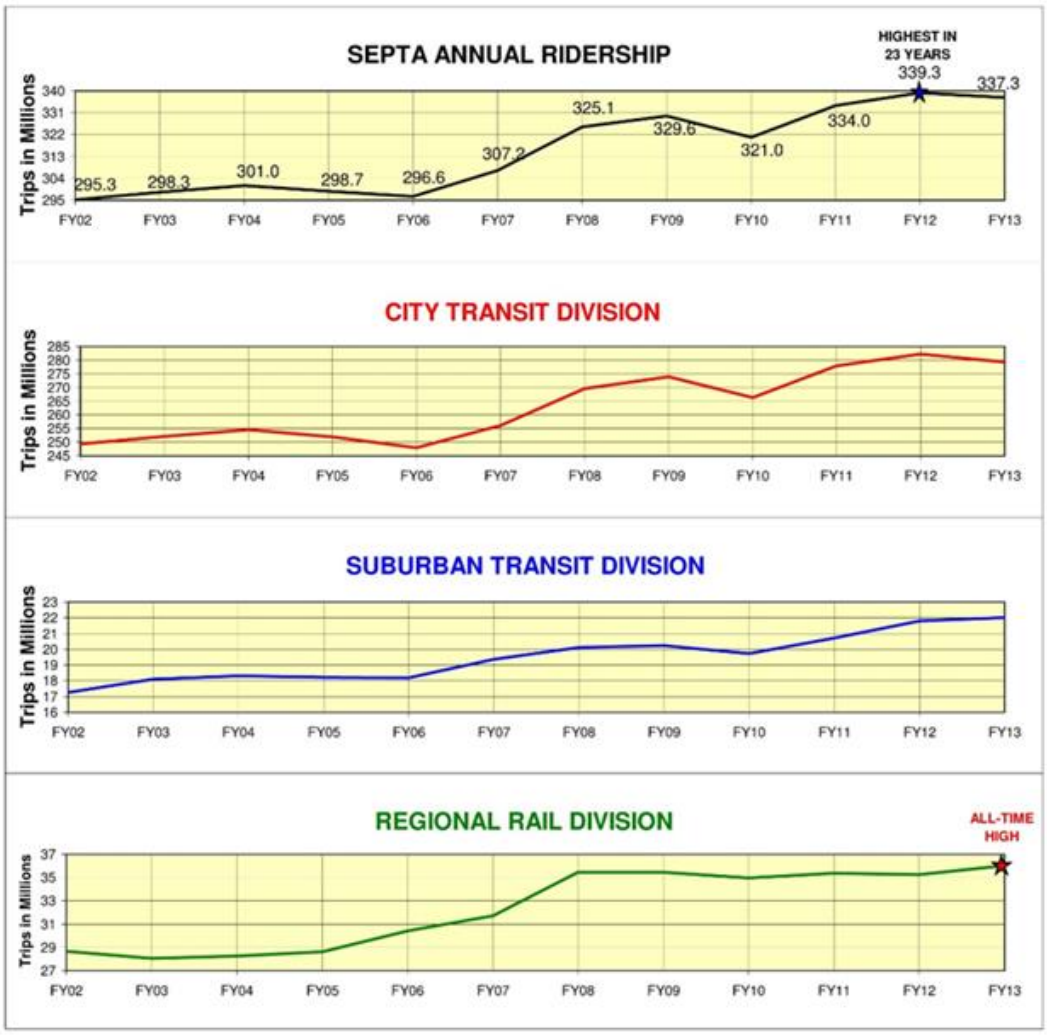
5.3.2 Ridership Trends

Figure 5.2 shows that ridership is at an all-time high across each of the agency's transit divisions. Three major divisions comprise SEPTA's city and suburban transit systems. They are its City, Suburban and Railroad divisions. The City Transit Division accounts for the agency's surface transportation routes for buses and trolleys. Several of its bus and trolley routes traverse Philadelphia's boundaries and extend into Bucks, Delaware and Montgomery counties. The agency's subway and elevated line routes, the Broad Street and Market-Frankford lines are also managed by its City Transit Division. The Suburban Transit Division is divided further by two districts, the Frontier and Victory districts. Victory operates bus and trolley routes for Delaware and Montgomery counties. Eastern Bucks and Montgomery counties bus services are provided by the Frontier District. Lastly, SEPTA's Railroad Division operates the agency's 13 regional rail lines, providing service to Southeastern Pennsylvania and Mercer County in New Jersey and New Castle County in Delaware.

Ridership during fiscal year 2012 reached an all-time high for SEPTA, a national trend that is attributed to commuters' quest to secure affordable and convenient travel options in light of rising gas prices, a sluggish economy, and greater commuting distances (Woodside 2008). Locally, the apparent decrease in ridership for the City Transit Division between fiscal year 2012 and 2013 is linked to "significant weather precipitation" per the agency's July and August 2013 Ridership Report (SEPTA 2013). Ridership for the Suburban Transit Division remained stable during this time period, however. This is due in large part to the

agency's ridership volume and composition in Philadelphia versus that of its outlying suburbs. For instance, the 2013 Ridership Report indicated that ridership counts were negatively influenced by school closings. Suburban school districts rely on school buses to transport students whereas urban school districts utilize them less due to budgetary constraints and the availability of transit options. The topic of school districts' dependence on public transit is presented in the following chapter as it pertains to ridership demand and expectations during extreme weather events. Lastly, the agency's Regional Rail Division ridership reached an all-time high in fiscal year 2013, a trend not only attributable to commuter thrift but also a changing commuter culture according to managers at SEPTA. When discussing the future of transit in the Philadelphia metropolitan region in the environmental sense, a manager representing the Office of the General Manager made the claim that "There is a generation that's coming in that's more concerned about the environment. They're moving back to the cities. They're not driving cars as much as my generation, and they're taking public transit. We're experiencing positive ridership. It's been the highest it's been in the last four years, and we're actually exceeding that this year." Further investigation of commuters' modal choice decisions is needed to pinpoint the factors that are driving these trends.

Figure 5.2 SEPTA's Ridership Trends



NOTED IMPACT:

FY 2008 ridership increase fueled by high gasoline prices despite fare increase.
FY 2009 ridership rises despite effects of recession beginning in mid-year January and lower fuel prices.
FY 2010 ridership impacted by six-day transit strike, two major snowstorms and weak economy throughout year.
FY 2011 ridership rebounds recording highest total since 1989, aided by high gas prices despite fare increase.
FY 2012 records ridership growth for second straight year as fuel prices range high between $3.30 and $4.00 per gallon.
FY 2013 impacted by Hurricane Sandy resulting in a two million trip loss, however RRD sets record for highest ridership.

Source: SEPTA Revenue & Ridership Report June and Fiscal Year-End 2013

5.3.3 Commuter Dependence on Regional Transit Systems

The following figures use data from the U.S. Census Bureau's 2007 – 2011 American Community Survey 5-year estimates to illustrate the levels at which commuters, whom reside in SEPTA's service area, depend on transit systems. Five-year estimates provide a greater degree of accuracy for analyzing local geographies according to the Bureau.[3] It is important to note that SEPTA's service coverage overlaps with that of NJTransit and DART, Delaware's transit authority. Commuters have been classified by the Bureau as workers 16 years of age and older that lack access to at least one private vehicle and use public transportation.[4] As such, they have been identified by the researcher as being vulnerable to transit disruptions of any kind. The census tract is the unit of analysis. The data was standardized using percentages to account for tract size differences. Census tracks with fewer than 100 persons were omitted from the analysis, since they represented airport facilities and other non-residential places.

Figure 5.3 shows the regional distribution of mass transit vulnerability. The highest concentrations of commuter vulnerability within SEPTA service areas are located in Mercer County, NJ (Trenton), Philadelphia County, PA (City of Philadelphia), Delaware County, PA (Chester City) and New Castle County, DE (Wilmington City). These places have the highest volumes of racial and ethnic minorities in SEPTA's coverage area.

[3] The distinguishing features between 1-year, 3-year and 5-year American Community Survey datasets can be found at the following webpage address www.census.gov/acs/www/data_documentation/summary_file.
[4] The 2005 – 2007 American Community Survey defines public transportation as inclusive of all vehicle modes, including rail, subway, elevated line, trolley, and bus.

Scholars suggest that certain racial and ethnic minorities are vulnerable to extreme events (Cutter et al 2003). The concentration of racial and ethnic minorities in SEPTA's coverage area is shown in Figure 5.4. These concentrations are heaviest in the region's central cities, including Philadelphia, PA, Trenton, NJ and Wilmington, DE. Blacks constitute the majority of racial and ethnic minorities in each case. The regional map shows that these concentrations lessen with distance from urban centers. However, several suburbs show heavy concentrations, including West Chester Borough in Chester County, PA and Norristown Township in Montgomery County. Thus, there is an apparent relationship between places with high levels of commuter dependence and racial and ethnic minorities.

Figure 5.5 shows the distribution of commuter vulnerability at the city-scale using Philadelphia as a case example. Philadelphia has often been referred to as a "city of neighborhoods" that has deep racial and class divisions (Adams et al 1991). Commuter vulnerability is spread across most of the neighborhoods. Neighborhoods such as Center City West and Center City East are high-income places. Land prices are among the highest in the city, since they comprise its central business district and administrative center. Also, fewer racial and ethnic minorities reside here.[5] Yet commuter vulnerability is just as high in these neighborhoods as it is in places like North Central in the northern part of the city and Point Breeze in the south. These are low- to moderate-income neighborhoods that also possess high concentrations of racial and ethnic minority residents. Neighborhood communities like Mount Airy in the city's far northwest section and Wynnefield have

[5] Center City's "Chinatown" draws exception to this observation. This ethnic enclave is located in East Center City.

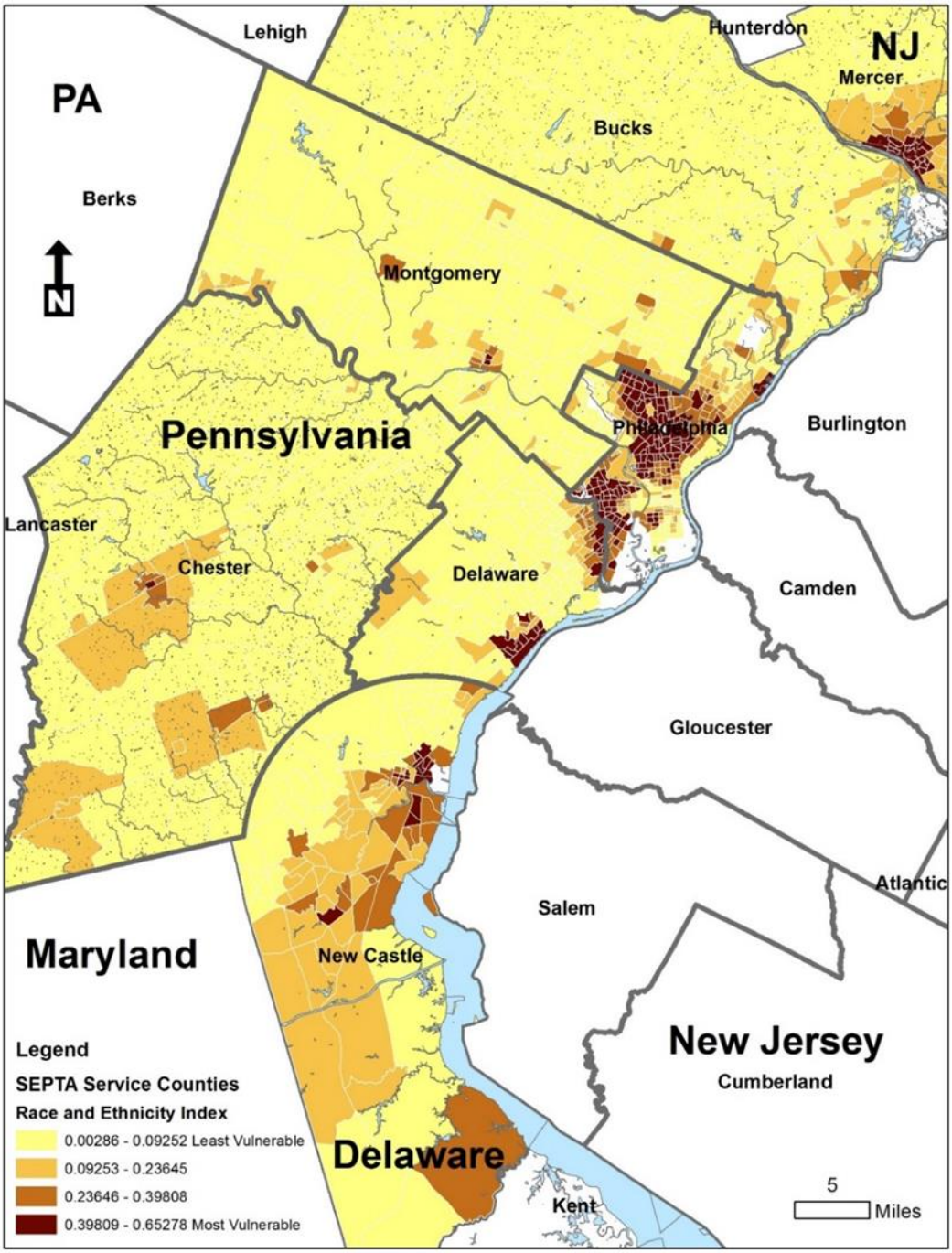
similar population concentrations but their incomes are higher by comparison. These neighborhoods too show moderate to high rates of commuter vulnerability. Figure 5.6 shows the distribution of racial and ethnic minorities at the city-scale to stress this point further. Figures 5.7 through 5.10 show selected transit departure and destination sites in North Central, Point Breeze, Mount Airy and Wynnefield neighborhoods to illustrate their environmental differences.

These illustrations provide the basis for a social vulnerability analysis which is beyond the scope of the present study. Involving actual commuters in such an analysis would be of great benefit. Although the agency provides reports on route statistics, having an idea of how commuters decide to make adjustments to transit disruptions would make for a more robust study. This can be better achieved through a block-level analysis of commuter vulnerability to transit disruptions.

Figure 5.3 Regional Distribution of Mass Transit Vulnerability

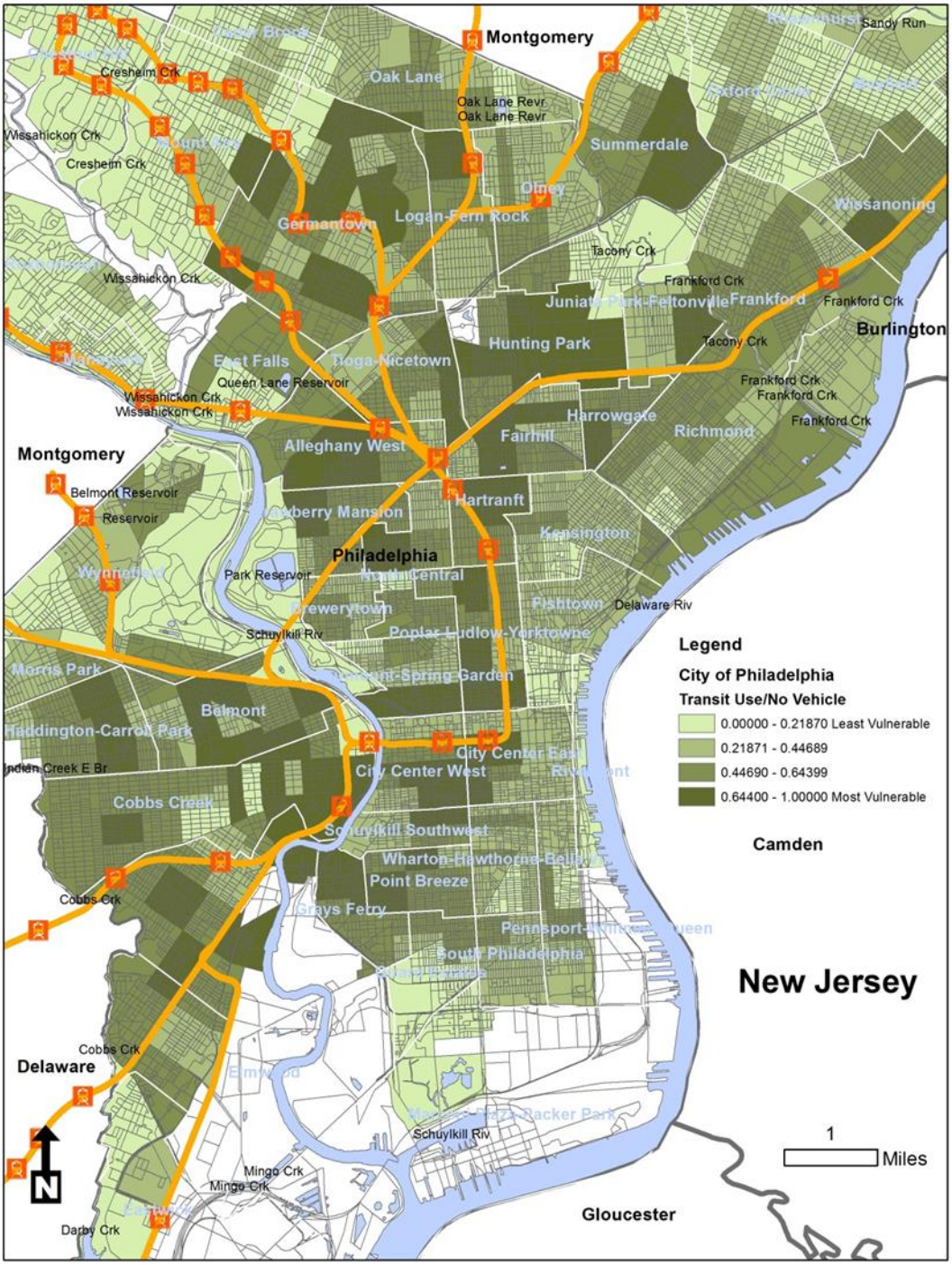
Source: U.S. Census Bureau 2007 – 2011 American Community Survey

Figure 5.4 Regional Distribution of Racial and Ethnic Minorities



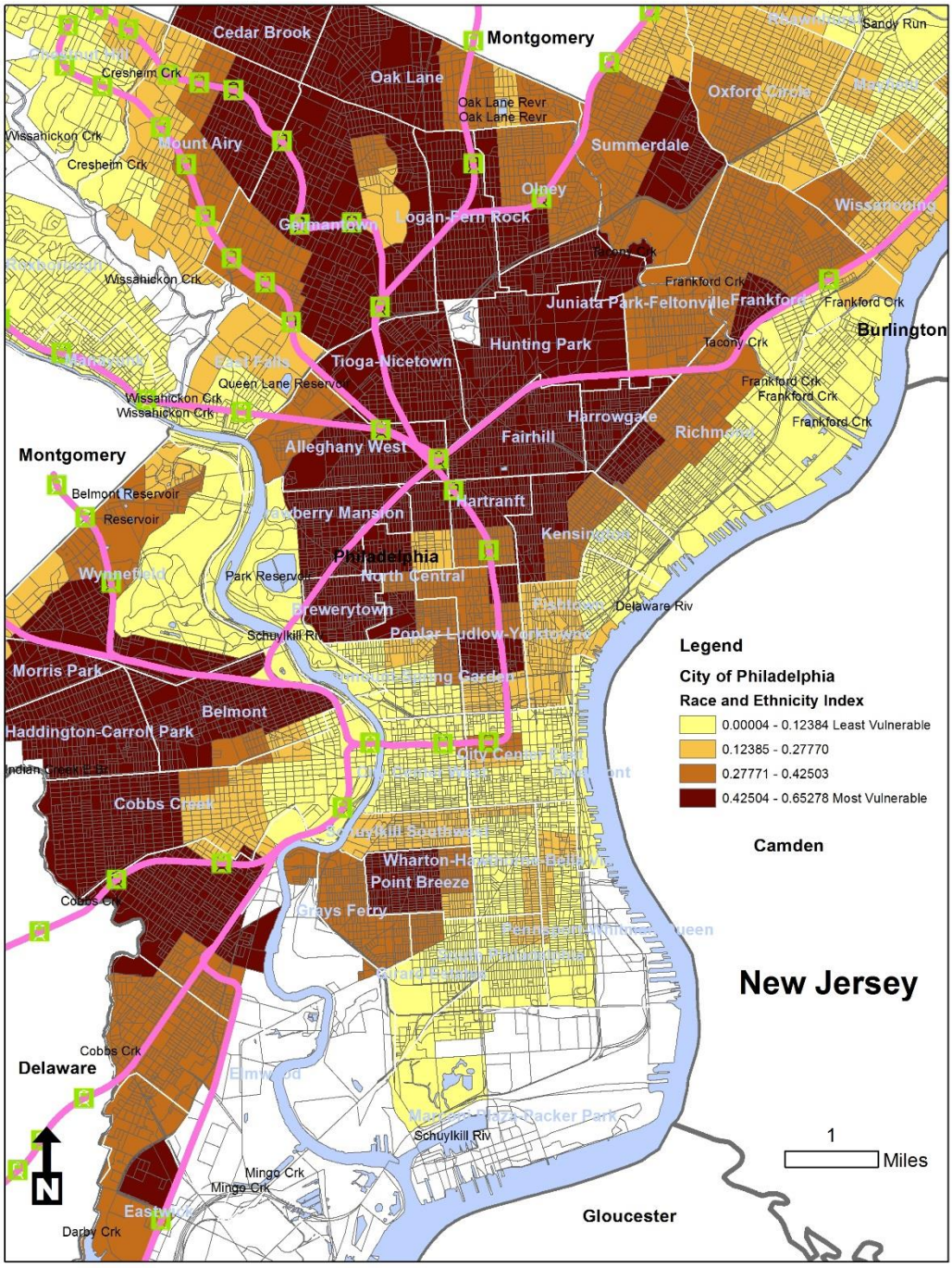
Source: U.S. Census Bureau 2007 – 2011 American Community Survey

Figure 5.5 City-level Distribution of Mass Transit Vulnerability



Source: 2007 – 2011 U.S. Census Bureau American Community Survey

Figure 5.6 City-scale Distribution of Racial and Ethnic Minorities

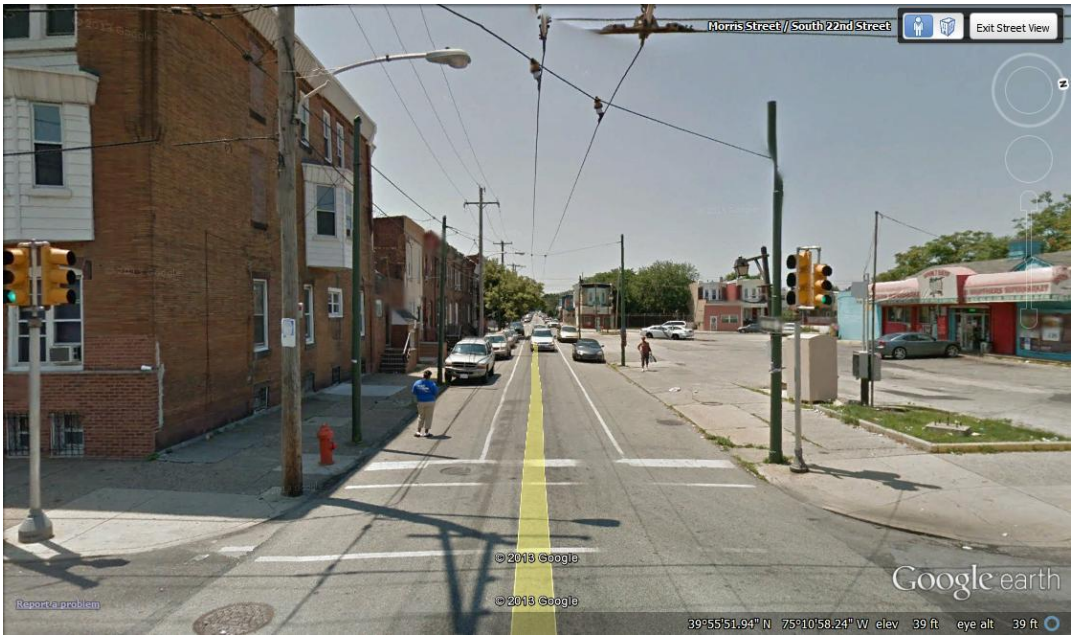


Source: 2007 – 2011 U.S. Census Bureau American Community Survey

Figure 5.7 North Central Neighborhood Bus Stop

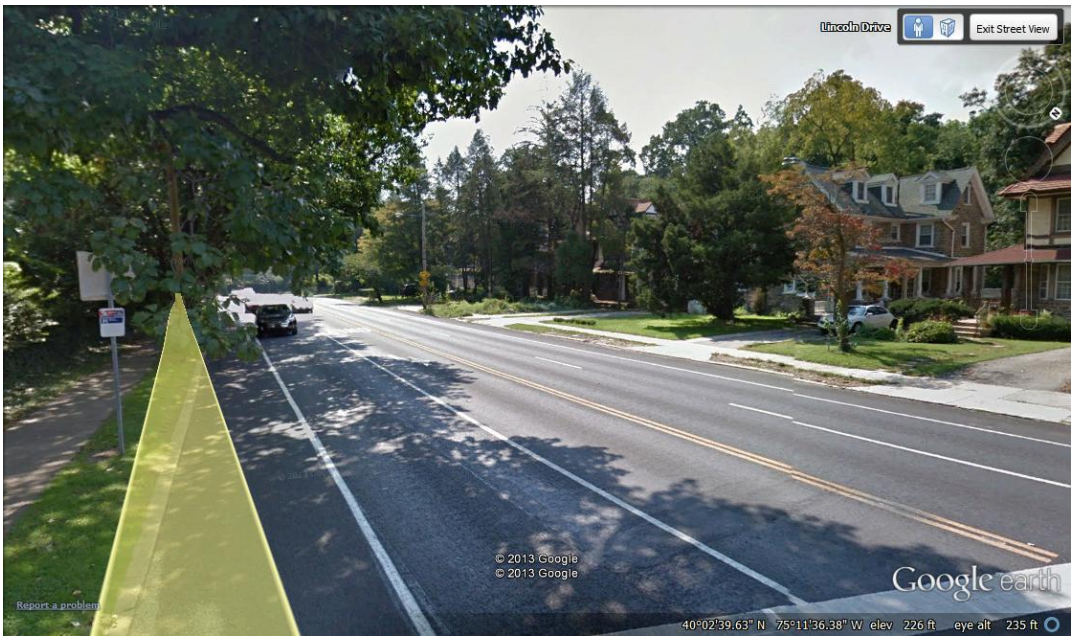
Source: Google Earth

Figure 5.8 Point Breeze Neighborhood Bus Stop



Source: Google Earth

Figure 5.9 Mount Airy Neighborhood Bus Stop



Source: Google Earth

Figure 5.10 Wynnefield Neighborhood Bus Stop

Source: Google Earth

5.4 SEPTA's Weather Management Tools and Strategies

SEPTA's Center City headquarters is the site of executive-level decision-making activities for severe weather events. It is equipped with a state-of-the-art Operations Control Center that consolidates and centralizes the management of each of the agency's transit modes. Figure 5.11 shows a visual display of the agency's transit information systems. In addition to using its transit information systems to locate and move different transit modes, managers use the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service to assess severe weather risk. They, in turn, use traditional news outlets, social media innovations like Twitter, and the agency's "web technology enhancements" and other travel service advisory resources such as its Schedules-to-Go, SMS cell phone text message feeds through ReadyNotifyPA, and TrainView for the purposes of service advisories. The agency stands by its claim that much has improved in how it communicates risk and severe weather adjustments to the general public and that its new policy has made a positive difference in the scale and magnitude of its system's resilience. However, uneven outcomes have resulted across the agency's transit systems on occasion. This topic is fertile ground for future research on communicating hazard risk to urban transit populations.

Figure 5.11 SEPTA Operations Control Center

Source: Clifton, Weiss & Associates, Inc.

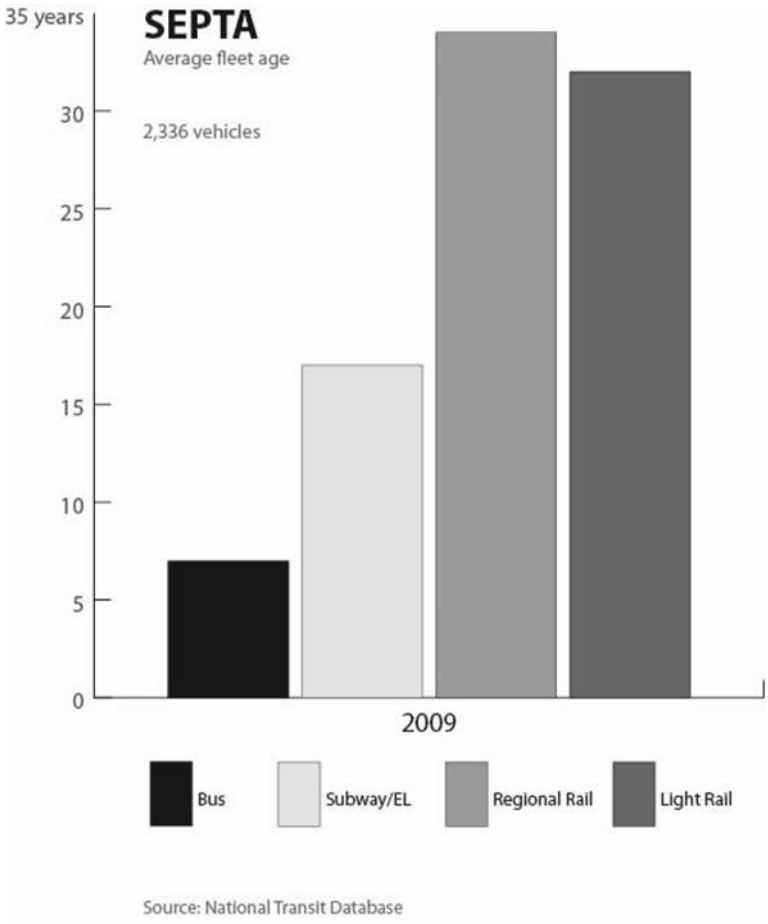
5.5 Resource Challenges and Constraints

As discussed in Chapter One, a mass transit infrastructure (including tracks, wiring, rail stations, etc.) in the Philadelphia metropolitan region is a century or more years old. In most places, this legacy system was built during the nascent years of county and township development along water body edges such as the Schuylkill River to take advantage of available rights-of-way routes and grade-level topographies. Stretches of railroad tracks, railroad and subway stations and other infrastructure equipment within SEPTA's service region were heavily neglected over the years by private owners and eventually abandoned by them and the agency due to financial disinvestment. New construction and capital

improvement projects have occurred across the system within the last ten or more years according to the agency's annual reports. Driven by the availability of funding these initiatives have been piecemeal in their implementation and lacked attention to environmental change trends.

Maintaining a state-of-good-repair for the agency's vehicle fleet adds another layer of stress to SEPTA's officials during the course of severe weather events. The agency operates a limited supply of vehicles that have either passed or are approaching the end of their useful performance life in many instances. Each one varies in vulnerability and resilience to severe weather events due to the nature of their design, travel distance, route type, and ridership capacity. SEPTA has upgraded portions of its vehicle fleet, particularly its buses as highlighted earlier. Figure 5.12 illustrates the average age of SEPTA's vehicle fleet according to 2009 reports.

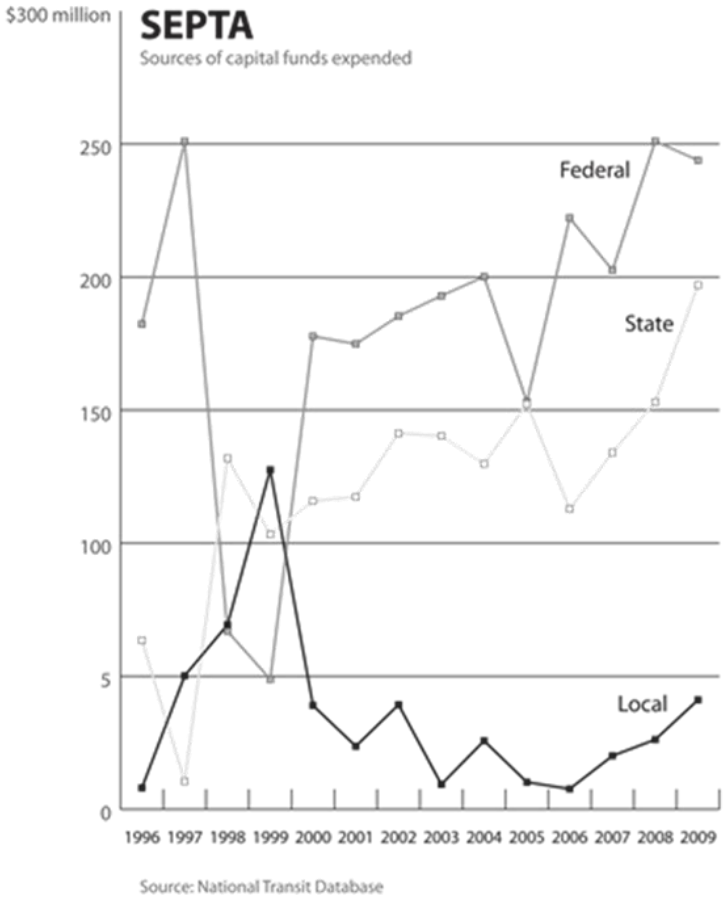
Figure 5.12 Average Age of SEPTA's Vehicle Fleet, 2009



The fleet's overall age poses as a problem as the agency attempts to integrate its new equipment with the old and vice versa. Vehicle age, ridership and route wear-and-tear, and weather-induced impacts combine to limit the performance and availability of all mass transit vehicles at times when they are in highest demand. Maintaining a good state-of-repair for its critical infrastructure and vehicles has often been the cause of much consternation among the agency's officials in their attempts at providing effective, safe and reliable service during the course of severe weather events and in the days and months leading to its systems' full recovery.

Figure 5.13 shows the investment trends among SEPTA's different capital budget sources. It is important to note here that SEPTA, like other mass transit agencies, receives capital project support when funds are made available through granting institutions. Funds are awarded on a competitive basis in most cases. There are rare occasions where this rule of thumb does not apply. For example, the American Recovery and Reinvestment Act of 2009 enabled SEPTA to implement its "shovel-ready" projects that involved the acquisition of hybrid buses, a bus loop and energy storage device. Generally speaking, there are no established formulas nor do long-term public investment commitments exist at levels that would allow SEPTA and other transit agencies to conduct system- and agency-wide projects that take into account necessary design and construction measures that limit or eliminate the impacts from severe weather events and climate change trends such as sea level rise. What funding a transit agency like SEPTA receives from governmental sources for capital projects has very tight and well-defined parameters. This is a problem because climate change adds premium costs to maintenance and development projects. Such costs have yet to be subsidized by the government according to agency officials. This will be discussed further in Chapter 6.

Figure 5.13 Sources of Capital Funds Expended



Weather-induced infrastructure damage and operational difficulties, though not an uncommon occurrence, come at a time when the agency's "financial situation is desperately bleak" as one SEPTA official put it. The global economic recession and decades-old downward trend in public investment in urban and regional mass transit reduce the likelihood of adaptation within the sector.

Greater frequency and intensity of severe weather events have been observed in the Philadelphia metropolitan region in recent years. This has serious resource implications

for the agency. The two weather types SEPTA agency officials cite as being most disruptive to their transit systems, infrastructure and modes are heavy precipitation and snow storms. Data collected from weather stations located in the City of Philadelphia that show their short- and long-term trend patterns are located in Appendix B. The following sections describe heavy precipitation and snowfall impacts on the agency's system and how it has dealt with them.

5.6 Managing Hurricane Irene in 2011

Riverine flooding is a serious and reoccurring problem for SEPTA. Flooded tracks and stations, rail bed and bridge washouts, tree obstructions, and signal house equipment fires due to severe precipitation events have been often the result of the combination of poor maintenance, insufficient protection, and eroded and modified landscape conditions. Most notably, the agency's Manayunk – Norristown Regional Rail Line is located several hundred feet alongside the Schuylkill River. Its tracks and several of its rail stations have routinely flooded during intense and frequent rainfalls in recent years. Also, the Trenton Transit Center, the terminus for SEPTA's Trenton Line and connection point to New Jersey Transit and Amtrak service, is situated less than 500 feet from the Assunpink Creek, a tributary of the Delaware River. During Hurricane Irene's arrival in August of 2011, the Assunpink Creek inundated the Transit Center's tracks. This resulted in the damage of several of the agency's rail vehicles and their subsequent decommission for several weeks for costly repairs and embankment washouts. Figure 5.14 of inundated SEPTA commuter rail cars at Trenton Transit Center and Figure 5.15 of an embankment washout in

Jenkintown, PA are provided. Several factors account for the damage and loss according to agency officials and media outlets, including SEPTA's decision to follow its severe weather plan to the letter and maintain its vehicles' holding position, the agency's disregard of government flood warnings, unprecedented area flood heights, and faulty track signals that were owned and operated by the Amtrak and CSX rail companies which prevented SEPTA from safely relocating its trains to more protected surroundings (Gordon 2011; Nussbaum 2011).

Figure 5.14 Inundated SEPTA rail cars post Hurricane Irene at Trenton Transit Station in New Jersey

Source: Associated Press

Figure. 5.15 Jenkintown Township, Pennsylvania rail track washout

Source: Courtesy of SEPTA

Urban flooding from heavy precipitation events exposes SEPTA's operational, managerial and engineering weaknesses. This occurs in different parts of the region and at different times of the year. In addition to impervious surface run-off from residential and commercial development, inadequate and poor storm water drainage systems exacerbate heavy rainfalls from hurricanes, tropical storms and large and rapid snow melts. Even though urban flooding is cited among agency officials as being less impactful on SEPTA's overall operations and critical infrastructure, rapid transit lines, rail and trackless trolleys, and ADA and shared-ride vehicles have all encountered localized and area-wide disruptions as a result of its occurrence, greatly reducing passengers' motility to reach their destinations. This has largely been due to a combination of factors, including SEPTA's route detour adjustments, congested city and state road networks, and equipment failures.

As a consequence, firms and other institutions heavily dependent on customers, clients and works which depend on the agency's services are inconvenienced in some cases and devastated for weeks and even months in others.

5.7 Managing Snowfall during the 2009 – 2010 Winter Season

Heavy and frequent interval snowfall events are described by SEPTA's operational and engineering personnel as crippling to many of its transit systems, including regional rail, trolley, and bus. Buses, commuter trains, trolleys, etc. were often heavily damaged by heavy snowfalls and weeks and months would pass by before they were restored to proper working condition in order to resume normal operations. The agency has attempted to solve this problem in recent years. This is evidenced by the introduction of a severe weather storm policy during the winter of 2009 - 2010 that led to a system-wide shut down of all the agency's transportation services for the first time in its history to reduce vehicle exposures to heavy and successive snowfalls.

Originally, the agency guided its operations by a winter season management plan. Under these guidelines SEPTA provided service to its ridership in extreme snow storm conditions until their intensity proved unbeatable and forced a halt. This operational practice often resulted in snowbound vehicles across city neighborhoods. It also led to rail fleet equipment damage that snow intrusion helped to cause. Vehicular breakdowns placed riders and operators at risk of being stranded in blizzard-like conditions. SEPTA maintains

that its new severe weather storm policy and practice raises not only the level of safety for its passengers and operating crews by giving them adequate notice of a shutdown, but it also allows the agency to bring its transit systems back to peak performance in shorter time intervals after heavy snow falls because it took the necessary measures to reduce equipment exposures to its effects. Today both the policy and the practice have been expanded to include hurricanes, tropical storms and other extreme weather events.

5.8 Discussion

Although it ranks among the largest in the U.S., SEPTA is but one of 7,088 transit organizations the general public depends on for affordable, safe and reliable travel services. The aim of this chapter was to explore the agency's underlying circumstances in managing extreme weather and taking steps toward climate change adaptation in the Philadelphia metropolitan region. In doing so, the chapter focused attention on the agency's history and service geography, its ridership, the tools and strategies it uses for managing extreme weather, its capital assets, sustained impacts from extreme weather events and its responses. A review of the agency's organizational features and dealings with recent weather extremes enabled a nuanced understanding of what its managers are likely to factor into their weather-related management decisions. Key observations are as follows.

First, an aged and deteriorated transit system that sprawls across many community types in every cardinal direction are among SEPTA's key challenges toward managing weather extremes and adapting to climate change. Each of the agency's systems possess particular

vulnerabilities not only on the basis of their locations but also their use. For example, stretches of the agency's rail infrastructure are exposed to riverine flooding. Bridge washouts, inundated stations and broken rail equipment including collapsed transmission lines have made for costly repairs that needed to be made immediately to ensure line service resumed within just hours of a storm's visit. Climate change adaptations such as infrastructure abandonment and replacement take time, require route changes, additional vehicles, and absorb large amounts of capital resources which managers suggest that the agency is lacking. With ridership on the rise, this implies that greater numbers of individuals and communities will be affected not only by capital projects aimed at adaptation but also by disruptions caused by extreme weather crises. The combination of the region's unpredictable weather patterns and the agency's current capital capacities makes riders' future ability to cope with more and prolonged disruptions uncertain despite the management tools and strategies it has at its disposal.

Second, dramatic ridership growth threatens both hazard vulnerability reduction efforts and adaptation. The delivery of more service with few and shrinking resources is a situation many transit agencies around the U.S. are struggling to cope with during a time of global economic recession and protracted fiscal recovery. SEPTA is no exception. This situation likely makes it difficult for the agency to efficiently and effectively expand services throughout the Philadelphia metropolitan region to avoid overcrowding and additional wear-and-tear on systems which may be stretched to or beyond their operational capacity (Woodside 2008). Where agency resources are scarce, the individuals who comprise the

bulk of its ridership community may encounter greater vulnerability risks, including females, persons between the ages of 35 to 54, and African Americans. Increased ridership demand acts also as a deterrent to climate change adaptation, since transit agencies like SEPTA will need to devote more time, worker energy, and capital resources toward building and sustaining their operational capacities. No evidence supports this claim better than the agency's inability to wholly modernize the transit system it inherited back in the 1960s and has since expanded on in the following decades as ridership demand grew in scale across Philadelphia and its surrounding suburbs.

Third, a transit agency's severe weather management tools and strategies are effective when the conditions are right for them to be so. SEPTA has been successful at repurposing its communications devices to alert its ridership of weather-related managerial decisions. Today it uses NOAA'S National Weather Service to track weather extremes, its Operational Control Center to organize and order vehicles during event cycles, and social media and other communication instruments to broadcast related managerial decisions. However, a couple of communications challenges remain for the agency. First, weather forecasting is not an exact science despite recent advancements in technological instruments. Surprises are produced by the most well-tracked weather systems. Thus deciding whether to operate or not carries varying degrees of risk for the agency due to the capricious nature of weather and the travel behavior of its passengers. Second, the ability to track vehicles does not translate into control over the obstacles that surround them. This is evidenced by buses that still were trapped by snows during the 2009 – 2010 winter season

despite the availability of the Operational Control Center's technologies. Lastly, consumer access, ownership and use of modern technologies are what likely makes a difference in whether the agency's alert systems are effective or not at varying spatial scales. Every passenger has the tools to receive digital alert messages is the assumption made by the agency. Generally speaking, people's resource capacities are uneven, particularly in urban environments. The types of alerts the agency employs have uneven effects on the basis of passengers' individual resource capacities. Therefore, the agency needs to somehow address these uneven capacities for the success of crisis interventions likely depends on them as ridership demand and use grows.

Decision-making is tied to available resources. The likelihood is high that SEPTA's current state of capital affairs will dictate whether and how it manages and adapts to future weather extremes. The data provided indicated that the agency possessed deficiencies in its vehicle fleet. Furthermore, it showed that government spending was on the decline and that other sources were at meager levels by comparison.

5.9 Conclusion

This chapter set out to outline SEPTA's managerial and operational circumstances when coping with extreme weather events. It gave a brief history of the agency's establishment

and its development, the geographic areas it serves, its ridership community, its capital resources within weather-related contexts, the tools and strategies it employs to manage severe weather, and how it has dealt with weather extremes in recent years. A discussion of these organizational aspects was also given. It highlighted pressing issues the agency faces toward managing severe weather in the future and taking successful steps toward adaptation. In doing so, it contextualizes the interviews presented in the following chapter.

Chapter 6

Managing and Adapting a Legacy Transit System for Weather Extremes

6.1 Introduction

On a near annual basis, hurricanes and tropical storm systems, heavy rainfall and snow, and heat waves reveal the managerial and operational weaknesses of urban mass transit agencies in the U.S. However, little has been written on these issues, and even now, the challenges, constraints and burdens transit system managers face in adapting to weather extremes are mounting. In addition to intensifying and more frequent storm activity, their particular problems include declining and stagnant financial support from federal, state and municipal governments, aging infrastructure, conflicting urban and suburban development regimes and more. In light of these and other matters, this chapter discusses the extreme weather and adaptation practices of the Southeastern Pennsylvania Transportation Authority and their related challenges. The content analysis is guided by the exploratory research questions presented in Chapter One:

(1) What are the extreme weather event and adaptation practices of the Southeastern Pennsylvania Transportation Authority?

(2) What challenges do managers at the Southeastern Pennsylvania Transportation Authority's face in handling weather extremes and adaptation?

The research presented here focuses on the Southeastern Pennsylvania Transportation Authority (SEPTA). The study explores its mangers' decision-making toward weather extremes and climate change adaptation. SEPTA's managers must often cope with severe weather impacts on transit infrastructure (e.g., commuter rail lines, rail stations, etc.) and travel modes (e.g., buses, trolleys, etc.) with limited budget and human resources. The results of the study may be instructive for planners, policymakers, and funders whose aims are to successfully adapt transit systems to climate change.

6.2 Research Approach and Methodology

Semi-structured interviews allowed for the acquisition of managers' recollections of and thoughts about severe weather management and climate change adaptation. The review and evaluation of decision-making on the basis of internal and external resource capacities are facilitated by semi-structured interviews. Pre-determined questions were designed to elicit interviewees' responses on issues related to severe weather management and climate change adaptation (Dunn 2005). Interview questions are provided in Appendix C. Interviews were coded inductively for analytical purposes.

6.3 Source of Data

Data was collected from SEPTA's managers during visits to the agency's Center City headquarters and Midvale Depot in the City of Philadelphia. Prior to conducting interviews

authorization was obtained from Rutgers University's Institutional Review Board (IRB). Agency permission was acquired from SEPTA's Public Affairs Office. Study approval documentation from SEPTA is contained in Appendix D. The study involved executive- and mid-level managers in SEPTA's organizational structure. A total of 8 managers participated in the study, including 6 men and 2 women. Persons represented in the study had high-level decision-making responsibilities in the Office of the General Manager, Operations Control Center, Finance and Planning, and Engineering, Maintenance and Construction. These persons included the General Manager, Chief Engineer, Director of Transportation (Bus and Rail divisions), Train Dispatcher, Strategy and Sustainability Planner, Assistant Director of Transportation (Subway and Light Rail operations), and Control Center Director.

It is important to note the limitation of this methodological approach. The small sample size in this study does not allow for generalizing the results to a larger population. Interviewees had twenty or more years of professional experience in the mass transit industry. Some study subjects began their careers as entry-level vehicle operators and dispatchers and climbed to the upper rungs of management. Participants' exposures to severe weather event management activities yielded crucial insights on decision-making within different resource contexts. The input of each interviewee proved invaluable to the research project as a whole, as mass transit adaptation to climate change is an obscure topic in the academic literature at this time.

Interviews were conducted between July 2011 and February 2012. Representatives from SEPTA's Media Relations Office supplied much-needed assistance in navigating organizational boundaries toward identifying study participants and scheduling face-to-face meetings with them. Nearly every interview was conducted absent the presence of a representative from the Media Relations Office. There is only one instance in which the Media Relations Office participated in an interview. This may have been done to ensure that interviewees' responses did not compromise the agency in any way. Whether this limited interviewees' responses to questions or corrupted the data in any way is unknown.

Interview questions were developed using the relevant literature on transportation cited in Chapter 2. Generally, interviews lasted for one hour to an hour and a half. Interviewees' responses to open-ended questions led to the generation of others during the interviews. This produced new topics for discussion and led to the development of relevant themes for analysis. Managers were interviewed individually and in groups. The original research design did not call for group interviews. However, group interviews led to richer conversations, as co-worker interactions generated dissimilar views on response effectiveness.

An electronic recording device was used to capture interviewees' remembrances, concerns and ideas associated with severe weather management and climate change adaptation. The study did not include bus, regional rail, subway or trolley operators who have first-hand

experience due to the nature of their work, because this was outside the scope of the study. Interview recordings were transcribed upon conclusion of the meetings. Transcripts were manually coded for managers' discussions on severe weather management and climate change adaptation. The online Coding Analysis Toolkit provided by the Qualitative Data Analysis Program in the University Center for Social and Urban Research at the University of Pittsburgh and the College of Social and Behavioral Science at the University of Massachusetts facilitated the coding process. The coding framework used in the study is provided in Appendix E. It is important to note here the limitations of this research method. First, coding is a subjective process. Second, no inter-coder reliability tests were conducted since I was the sole coder. Third, the small sample size of interviewees does not reflect the views of all transit managers employed at SEPTA or elsewhere. Lastly, there is a high degree of certainty that other transit agencies encounter unique challenges during severe weather and fashion their management and adaptation responses as such.

6.4 Research Findings

6.4.1 Extreme Weather Management Practices

Table 6.1 shows examples of the agency's extreme weather management practices. The agency has had to repair or build new infrastructure to mitigate impact damage from storm events and to prevent future harm. Pre-event preparation activities vary by weather type. The agency completes a checklist of activities which need to be completed before the arrival of a storm event. These activities range from the application of substances to

remove ice and snow from outdoor station platforms to sandbagging vent wells to manage subway tunnel flooding during heavy precipitation events. As previously discussed, the agency adopted a new storm policy during the 2009 – 2010 winter season. When weather forecasts and advisories indicate likely risks to human life and property, agency managers cross-reference them with organizational knowledge of vulnerable places and systems to evaluate where and when to suspend transit services (e.g., bus, rail, trolley, etc.). The agency uses social media, mobile technologies, its website and other communicative devices to inform the general public of transit delays or system shut downs resulting from extreme weather events. In recent years the magnitude and frequency of storm events have resulted in the agency's growing dependence on contractors to assist with repairing damaged infrastructure or debris removal to resume disrupted transit services.

6.4.2 Adaptation Practices

Table 6.2 shows examples of adaptation practices the agency performs. These practices are anticipatory in their implementation rather than reactive in comparison to extreme weather management. For example, the combination of ground saturation from heavy or sustained precipitation events and heavy winds have a tendency to uproot trees that fall on energy transmission lines which power the agency's electrified railroad. In order to reduce the incidence of railway disruptions resulting from collapsed energy transmission lines, the agency manages an aggressive tree trimming and removal program. Subway tunnel flooding influenced by municipal street maintenance projects is being addressed through the agency's restoration projects. The agency seeks external funding support to address

future flood impacts to its railways. Lastly, the agency is creating more suitable travel environments for passengers through investments in heating and cooling systems for waiting places such as rail station platforms.

Table 6.1 Examples of SEPTA's extreme weather management strategies

Passage	Classified as
We were having problems out at Radnor trying to continue repairing the damage from the August hurricane. The embankment was 40-50 feet, and we couldn't stabilize it because it kept on shifting no matter what we put in . . . ballasts to shore it up and the next day it would sink another 4 inches. So we had to build a whole new structure to deal with that, that wasn't there before.	Post-event recovery (construction)
But I can tell you we have every year a letter that comes from my office, and we just basically take the winter preparation letter from the year before and whatever we learned we incorporate and it's the same letter that rolls out and the same checklist of things that have to get prepared.	Pre-event preparation
We've gotten creative where we now go into the computer and we look at the NOAA site for their hydrologic predictions so we know what rivers are . . . affect us. We know our prone to flooding and we'll look in advance of the potential heavy rain storms and we know that we will lose a couple of our rail lines but beauty of it is . . . is that we don't have a train stuck in the middle of a track with water all around it because we'll react before that occurs because we're using the data that is available to us.	External information sources
Let's take the service back, and let's try to hold onto our [rail car] equipment and provide service when the snow storm is over. And if people want to start coming back, coming back out . . . And we've done that with our buses too. By suspending service. Instead of having 150 buses stuck the following time we had suspended service was 40. So holding onto our resources for when the service starts to resume.	Transit service suspension
You can find out where your train is. You can tell where your stuff is now. When you have a delay you can get Twitter, Ready PA . . . there's a whole bunch of mess you can get. You can sign up for a specific route. And all this information is given to you and that's how the news media is picking up now. They all get from our Twitter or our information group that puts out all this information.	Mobile technologies for travel advisories
So, initially, we used to do the Norristown high-speed line all with our own forces, then we put out 1/3 one year for contracts, 2/3 the next, and now we're up to the entire line. We have the option. If it's a minor storm, we'll deal with it with our people. If it's a major storm, we'll go with all contractors. That frees us up to have people to deal with the other lines that we have in that area and not over-burden our employees or create situations that are unsafe for them, working too long, too hard.	External support

Table 6.2 Examples of SEPTA's adaptation practices

Passage	Classified as
One of the things that we deal with is tree trimming, bringing down trees to make sure that they're not . . . the ones that are closest to the tracks that we're able to tree trim em' or take them down. So when we do get water damage they don't fall on the catenary and take down the catenary.	Modifying natural environments
And so we're actually now putting a plan together to . . . with our in-house forces just go after the stretches where we typically see too much water coming into the subway with the very little curb, and we're going to put back the full eight inches of curb.	Structural fixes
I know that they've been working on this. There's even funding available now. I know that we're probably going to apply for [FTA] funding [for adaptation assessment] because one of our lines along the Schuylkill River keeps going under water up in Norristown and we're looking if there are ways to mitigate the flooding there.	External funding
We are starting to provide heat in some of our lines where it's the farthest from the city . . . the conditions . . . on the Doylestown branch of the Paoli Line. We're starting to put heat in the shelters outdoors that come on . . . you can press the button and it will come on.	Environmental conditioning

6.5 Analysis of Extreme Weather Management and Adaptation Challenges

The major themes relating to challenges and constraints managers faced in managing weather extremes that emerged in interviews were: (1) managerial philosophy; (2) external expectations and demands; and (3) organizational stress. For climate change adaptation, these themes were: (1) location of transit infrastructure; (2) condition of transit infrastructure; and (3) capital resources. These themes emerged from the coding process which produced 32 separate codes. A graph of the codes is provided in Appendix E. Remarks emphasizing organizational stress constituted the bulk of managers' responses to interview questions. In total, there were 26 or 12.15% of responses relating to organizational stress. Agency philosophy accounted for 7.01% of responses.

6.5.1 Extreme Weather Management Challenges

6.5.1.1 Managerial Philosophy

Managerial philosophy gives unmistakable direction and value to the agency's extreme weather management practices. After being asked about what led to the new storm policy, interviewees suggested that the agency's prior philosophy once stood as a challenge to transit system resilience. It resulted in severe financial costs to the agency. A manager in the Office of Engineering, Maintenance and Construction explained that the "old philosophy was let the subway flood, make a big capital project, and do a massive thing" fifteen or more years ago. Executive-level leadership has since changed and today values cost-saving measures that help to protect equipment (e.g., buses, rail cars, etc.) and infrastructure from weather-related damage.

Respondents suggest that the change in storm policy was also largely due to a shift in agency culture. When asked how the agency managed extreme weather events in the past a railroad manager in the Operations Control Center explained that "[severe weather management] was more of an ad hoc type of approach at solving problems" and "the railroad did not pay that much attention as a plan was concerned when severe weather would approach." Managers' evaluations of near disasters were significant in changing the agency's cultural mindset. The same interviewee recalled how the agency's previous philosophy of continuing system operations despite extreme weather events led to an incident that involved the use of a rowboat to evacuate passengers from a rail car as it

flooded while in transit. He stated that "We were trying to serve our people as long as possible without thinking about the consequences of what might happen if things went wrong."

The agency has since abandoned extreme weather management practices that jeopardized passengers' lives for the sake of institutional liability. Managers expressed how important it was for the agency to undo past mistakes in decision-making to not only ensure passenger safety but to also project a positive image of organizational strength for revenue generating purposes. Over the years, the agency experienced its fair share of unfavorable news coverage of its reactive responses to weather extremes and their attending failures.[6] Proactive agency responses today such as reducing subway flooding by covering up vent wells are the sorts of activities that lend themselves to favorable news stories. Interviewees suggest that substantive and visual actions to reduce its weather hazard risks allow it to avoid being made a spectacle by the local media and boosts riders' confidence and satisfaction in the agency. When discussing all of the protocols and procedures the agency enacted to prepare for Hurricane Irene, a respondent representing the agency's Office of Engineering, Maintenance and Construction remarked that "We don't want to make the news for our maintenance problems or for our weather problems." However, when asked about the possibility of having to manage weather extremes in the future as a result of climate change the same interviewee responded by saying "I don't think we sit down and

[6] The agency's Media Relations Office shared its library of electronic news coverage of extreme weather events. Most news coverage emphasized the positive benefits of the agency's responses to extreme weather.

have a five-year plan on how to continue to battle the weather but I think that we realize and try to learn from our mistakes and try to improve every year coming out of the gate . . ." This statement illuminates the agency's emphasis on weather extremes as they come rather than a concern for climate change as it will be. This represents an important challenge to climate change adaptation for the agency.

6.5.1.2 External Expectations and Demands

Respondents suggest that the combination of commuter rational and behavior often results in transit system "crush loads" the agency is ill-resourced to manage even under normal operating conditions. Managers indicated that commuters who regularly use private vehicles for different travel purposes have a tendency to switch over to mass transit during inclement weather, since they expect the agency to provide service despite forecasted and actual conditions. A manager in the agency's Office of Engineering, Maintenance and Construction pointed out that in "a 12 or more inch snowstorm people leave their cars at home and migrate to transit." He added: "So now all of a sudden we're already at peak capacity. Now you have all these people that generally drive come to transit. We can't provide enough [rail] cars so we're packed like sardines." Referring to the degree to which ridership demand influences extreme weather decision-making, a manager in the Operations Control Center shared that "One of the factors that goes into our thinking [on voluntary system shutdowns due to weather extremes] is that if people hear that we're running they expect our vehicles to be on time." Today when managers determine that transit systems will be overwhelmed by the combination of extreme weather and increased

ridership demand, then the decision to voluntarily shut down route services is likely to be made to achieve several goals. These goals include protect commuter safety, reduce equipment loss, and ensure system resilience.

Referring to schools in the City of Philadelphia, an operations manager at the Midvale Depot explained that "one of the worst things [school districts] can do" is close schools early because "they think that we can just magically make 300 buses appear." This comment seems to reveal the agency's resource limitations and the challenges of handling greater numbers of passengers unexpectedly. The same interviewee further commented on how the timing of crisis events "affected" the agency's management responses. In recalling the 2011 earthquake that forced mid-day building evacuations of hundreds of thousands of workers throughout the Philadelphia metropolitan region and throughout other parts of the east coast, the interviewee highlighted the agency's operational circumstances as a challenge to the successful dispatching of vehicles stating that "The way we're set up, the majority of the workers work in the morning hours and the evening hours." The agency needed to make immediate adjustments to its operations schedule due to the suddenness of the event as well as provide emergency overtime pay to operators, a financial cost the agency could ill-afford since its "financial situation is desperately bleak" according to one manager in the Office of the General Manager.

6.5.1.3 Organizational Stress

While managing extreme weather events appear to have grown to be a part of the normal routine for the agency, evidence exists that shows it has grown to be more of a challenge for managers and workers to handle. Respondents point to the frequency of events as being an acute management challenge which drains the employees. A manager in the Office of Engineering, Maintenance and Construction explained how ""[Dealing with extreme weather is] almost like a dance . . . just feels like the dance is getting faster. It's harder and harder to catch your breath between the events that come up." In recalling Hurricane Irene in 2011 and Tropical Storm Lee which followed just days after the storm, the same interviewee discussed how the temporal spacing of events disrupted the agency's "normal maintenance and construction programs." As he put it, the "lingering effect" of severe weather events lasted for several months and adversely influenced the work schedules of engineering workers who not only had to repair erosion, embankment and slope damage to the railroad after Hurricane Irene but also needed to attend to capital projects already in the pipeline. Reportedly, the agency in recent years has had to depend more on contractors to alleviate pressure and stress that severe weather events exert on the agency's workforce. Citing "increased safety requirements" from the federal government, worker stress and safety as a major factors in the decision to depend more on contractors, the same interviewee explained how the agency "used to [prepare and repair] the Norristown high-speed line all with our own forces, then we put out 1/3 one year for contracts, 2/3 the next, and now we're up to the entire line." However, contractors are enticed by larger payouts from agencies with emergency work needs which take longer time to complete. Often, "they don't live up to their contracts because they go where the money is" according to the

same interviewee. This results in the agency having to deal with recovery pairs that may take longer than anticipated to complete, leading to prolonged disruption on different parts of the transit system.

6.5.2 Climate Change Adaptation Challenges

6.5.2.1 Location of Transit Infrastructure

The location of transit infrastructure is a major challenge to conflict-free adaptation. Referring to development that has occurred in what had been rural communities throughout the Philadelphia metropolitan region, a manager from the Office of Finance and Planning discussed the agency's outlook on adapting transit infrastructure when asked what the foreseeable problems were in dealing with suburban and urban places. When recalling the FTA grant meeting, the same interviewee spoke of "downstream impacts" which were an agreed concern among other interviewees. The following statement succinctly illustrates this idea:

> "The line that we've chosen to study is a perfect example of this. The Manayunk-Norristown Line runs along the Schuylkill River so it has the flooding impacts from the River. Eight of the last ten high-water marks have occurred in the last ten years at Norristown. But on the other side, uphill, it's kind of squeezed between a hillside and the river you have massive storm water runoff issues from development that's occurred on the land side. And so you got flooding on one side and erosion on the other side and it's combining and hitting us right on the same track area. And so you got flooding, you also got track bed erosion and things like that . . . and you got it between the city and the suburbs where . . . You know, where do you do your impact infrastructure work because if you do it in one place you're going to affect the community down the river. So it's a big issue." – Interviewee C

Managers representing the Offices of the General Manager, Finance and Planning, and Engineering, Maintenance and Construction showed common agreement on the need to "look at [climate change adaptation] holistically as a region" in order to avoid unintended impacts across urban and suburban communities. When they were asked whether the agency was prepared to deal with conflict from adaptation projects they saw might result in unintended impacts, one manager responded that "It's really too soon to answer that question because we're just starting this [adaptation] process now." Following this statement, he offered reassurances that the FTA's grant would position the agency to be less reactive to community impacts from physical projects and that its "teams are so used to doing the fire drill . . . to deal with the stakeholders."

6.5.2.2 Condition of Transit Infrastructure

The age of transit infrastructure (e.g., bridges, railroad tracks, subway tunnels, etc.) the agency owns and operates is viewed by managers as an incredible obstacle to adaptation; and a source of large disappointment with regards to its relationship with the federal government. Interviewees communicated the difference between newer and older transit systems as they concern adaptation challenges, suggesting the agency was at an extreme disadvantage in this regard. One manager protested that "It's much, much more difficult than starting from scratch like the airport is and saying we're going to build this runway five feet higher because we think the Delaware River is going to flood five feet higher. Much different, and it's much more difficult to start with one hundred year old infrastructure and try to adapt it." The same interviewer also pointed out that it was

government's responsibility to aid the agency in dealing with its infrastructural circumstances, citing that newer and older systems were "Two completely different issues, and need to be addressed as such at the federal level." The agency's general manager has combined forces with other similarly situated agency's to advocate for increased spending on older transit systems in the U.S., including those serving Chicago, New York, New Jersey and also Washington, DC. In discussing the particular challenges associated with older rail systems, the agency's general manager drew an important distinction in the way they have been historically funded by stating "It was all constructed with private dollars way back when . . . it's not going to last forever. It's time to reinvest in those assets. Quite simply, there's never been enough money to do that." During this group interview, managers expressed dissatisfaction with the federal government's investment in new system expansion when they spoke of the need for higher public investment in state-of-good-repair projects the agency sorely lacked. The age of the agency's infrastructure and its relationship are by no means a new challenge for its managers. However, climate change creates a new context for them both. The view that government has a high degree of fiscal as well as moral responsibility to adapt the agency's may very well be the leading factor that make its managers open to options that may not serve in the best interest of different metropolitan places and peoples.

6.5.2.3 Capital Resources

The importance of capital resources loomed large for managers when asked about the challenges to localized and system-wide adaptation. Managers pointed to climate change

uncertainty as well as safety and financial risks as major factors in decision-making on whether or not the agency should or was in a position to afford adaptation, since the agency's "financial situation is desperately bleak" as one manager put it. These observations illuminated what managers believe the agency needs to achieve through adaptation versus what the government lawfully tasks it to do. However, managers did not make the kinds of connections between what types of damage impacts from weather extremes the agency had encountered and what it will likely face in the future. For example, one manager commented that "From a resource standpoint, we have to weigh our risks against the climate changes versus other areas where we might have a bridge that needs to be repaired or a federal mandate like positive train control that we have to do." This illustration shows how managers may separate or divorce climate change from current capital issues that severe weather events amplify. Another manager showed the same outlook when he explained "Again, it's risk. Do you invest a hundred thousand dollars to remedy a problem or risk a washout that's going to cost you a quarter of a million dollars if that happens? These are things we have to discuss." It is worth noting here that managers representing the Offices of the General Manager and Engineering, Maintenance and Construction made these statements.

6.6 Discussion of Results

As I close this chapter, it is essential that important findings from my literature review in Chapter 2 be referenced while discussing the research results presented in this chapter. First, I highlighted how the current literature on weather-induced transport hazards

overlooks the importance of understanding why and how transit professionals develop and implement weather management policies. The results of my research indicate that managerial philosophy gives overall direction and value to the agency's efforts to mitigate organizational risk and liability during the course of short-term extreme weather events. No respondents spoke of how managerial philosophy drove adaptive responses needed in the long-term, however. Managerial philosophy relating to weather extremes largely changed over time in response to in transit liability. This can be taken to suggest that the agency has yet to take a long-range view of the issue at hand and make a long-term commitment to invest in climate change adaptation. Strong evidence of this was presented by the manager representing the agency's Office of Engineering, Maintenance and Construction. He noted how the agency did not have a five-year plan to "continue to battle the weather." The lack of long-range planning regarding climate change has important implications should weather-related disruptions in the Philadelphia metropolitan region become more frequent. If not addressed through proper adaptation measures, continuous weather impacts can further degrade and destabilize transit infrastructure to place greater numbers of riders and communities at risk.

Second, the literature review discussed how little we know about the factors that transit officials account for when coping with weather extremes despite our present knowledge of transportation hazards. The current research speaks even less to managerial decision-making on transportation adaptation to climate change. The results of my research showed how both external demands and expectations and organizational stress might influence

whether and how a transit agency like SEPTA might fashion short- and long-term responses to weather extremes. When weather conditions grow severe and demand becomes greater as a result, the agency may likely suspend service because it lacks the resources to deal with the capacity. However, depending on the timing of the event, this has serious consequences for vulnerable populations such as school children. The agency lacks the equipment to accommodate mass population dispersals. The agency's current resource limitations is particularly problematic in light of increasing ridership as shown in Chapter 5, since the public looks toward it to provide service during crisis events. Certainly, it is evident that the agency and its municipal partners will need to update existing emergency plans to account for both the agency's equipment limitations and the region's increasing dependence on transit. When it involves organizational stress, the need for critical evaluation of the agency's resources is perhaps even greater. The research results reveal an agency that not only is trying to do more with less but also one that has, in some respects, has reached its limit. This may not only influence the quantity of services that it can provide during or after weather extremes but also the quality despite the agency's best intentions. For vulnerable places and populations the agency's ability to ensure transit system resilience is critical. More attention needs to be given to how agencies like SEPTA are able to cope with extreme weather impacts with their in-house resources, since external resources are unreliable and unavailable at the moment.

Third, the physical vulnerability of transportation systems to climate change is the dominant view in present-day research in the literature. The analysis of U.S. state and

municipal planning and policymaking documents in Chapter 3 indicated the same. The research results in this chapter corroborate these findings. When speaking about the challenges of climate change adaptation, managers emphasized the age and physical condition of transit infrastructure. These matters received no attention in conversations about extreme weather management. However, managers speak strongly about passenger safety during extreme weather events. Also, when presented with the idea of people's vulnerability to proposed adaptations such as new facility construction and abandonment, managers deflected questions about how the agency would address conflicts with communities that might likely surface albeit they acknowledge potential "downstream impacts." This is an important finding because managers appear to separate extreme weather management from climate change when it comes to people. On one hand, managers show a profound concern for the safety and security of passengers when they are on board their vehicles. There is a degree of disconnect for non-riders and their communities on the other as far as adaptation is concerned. This situation may be largely due to the uncertainty surrounding climate change, adaptation's different possibilities, and managers' outlook on financial and perhaps political risks associated with climate change and adaptation.

Lastly, the literature on institutional decision-making on climate change adaptation yielded important insights. The agency has made incremental movements toward improving its extreme weather management practices and adaptation in hopes of avoiding tragic errors in risk-taking through conscientious decision-making (Dholakia-Lehenbauer and Elliot

2012). However, "historical institutional structures" such as the agency's governmental obligations restrict it from taking the types of actions it needs to fully adapt infrastructure to new climate regimes (Agrawal 2010). In addition to government mandates for safety measures, managers spoke of how past and current government funding has limited its ability to maintain an acceptable state of good of repair for the agency's transit system. The findings of my research also indicate that the agency has sought innovative ways to adapt despite its resource limitations to defy institutional inertia as some would suggest (Harries et al 2011; Naess et al 2005). Yet voluntary transit system disruptions and the agency's use of mobile technologies may cause differential effects among riders, since people's vulnerabilities or adaptive capacities are uneven on the basis of their socio-economic and place-based circumstances. This shows the need for greater attention to be given to the socioeconomic vulnerability of people to transit system disruptions whether caused by extreme weather or adaptation impacts.

6.7 Conclusion

With the use of semi-structured interviews with 8 managers from the Southeastern Pennsylvania Transportation Authority and a content analysis of their transcripts, the researcher characterized the agency's practices in extreme weather management and climate change adaptation. It also enabled an analysis of the challenges these managers face while attempting to perform both practices. A subtle quote from one of the interviewees packs a huge punch toward capturing the full essence of their challenges. The

interviewee slyly stated that “We can’t assume that everything’s going to be operating the way it was designed because things happen.” Nothing can be further from the truth when thought is given to the changing global environment and the people and places which it influences and vice versa. In short, everything changes and decisions surrounding extreme weather management and climate change adaptation for transit systems must follow suit as well.

Chapter 7

Conclusion: The Future of Weather Management and Climate Change Adaptation for a Metropolitan Transit Organization

7.1 Introduction

This dissertation set out to explore the future of extreme weather management and climate change adaptation practices of the Southeastern Pennsylvania Transportation Authority (SEPTA) through an examination of its past and present circumstances. It was done in hopes of providing insights into the challenges, constraints and opportunities toward extreme weather management and adaptation a metropolitan transit agency faces which current research agendas lack. In so doing, it has identified the current state of climate change adaptation planning and policymaking affairs among U.S. states and municipalities, the agency's managerial and operational circumstances, and the factors and motivations behind the agency's decision-making on weather risk management and climate change adaptation. In light of actual and potential weather-related transit system disruptions, this exploratory effort was guided by the following research questions:

(1) What plans and policies do U.S. states and municipalities have for adapting transportation systems to climate change?

(2) To what extent does climate change adaptation planning and policymaking demonstrate a priority concern for mass transit systems?

(3) How have extreme weather events in recent years affected the Philadelphia metropolitan region and its transportation systems?

(4) What are the managerial and operational circumstances surrounding the Southeastern Pennsylvania Transportation Authority's management of extreme weather?

(5) What are the extreme weather event and adaptation practices of the Southeastern Pennsylvania Transportation Authority?

(6) What challenges do managers at the Southeastern Pennsylvania Transportation Authority face in handling weather extremes and adaptation?

In addressing these questions, this investigation of extreme weather management and adaptation for a transit agency fills a gap in transport, hazards, and environmental change geography research subfields. With this concluding chapter, I present summary research findings, the study's theoretical and policy implications, and its limitations. The chapter wraps up with future research pathways.

7.2 Summary Research Findings

The main empirical findings are chapter specific and were summarized within the respective empirical chapters. This section will synthesize the empirical findings to address the study's research questions.

(1) What plans and policies do U.S. states and municipalities have for adapting transportation systems to climate change?

a. **The central focus of climate change adaptation planning and policymaking efforts among U.S. states and municipalities is the physical vulnerability of transportation systems to weather extremes**: Few planning and policy efforts emphasized people's vulnerability to transit disruptions resulting both from extreme weather events and recommended adaptation measures, including facility abandonment, route closures, new construction, etc. People's circumstances and travel behavior hold the potential to render proposed adaptations in planning and policy documents ineffective and even disastrous once implemented.

b. **In many instances, adaptation funding sources and finance strategies are absent:** Strategies and recommendations for climate change adaptation for transportation systems are plentiful, but without credible finance options and access to the actual resources their implementation is highly uncertain for transit organizations dealing with budgetary crises resulting from the combination of economic recession and slow recovery, extreme weather events, and daily operational issues.

(2) To what extent does climate change adaptation planning and policymaking among U.S. states and municipalities demonstrate a priority concern for mass transit systems?

a. **Transit systems and their agencies are underappreciated in state- and municipal-level adaptation planning and policymaking**: Few states and municipalities in the study acknowledge the particular problems urban transit systems and their agencies face. It is uncertain whether all levels of government will supply transit agencies with much-needed monetary resources to incorporate climate change into capital projects, since they have been given low-level priority in funding, planning and policymaking schemes at the present moment.

b. **Transit dependent communities and the disproportional impacts of transit disruptions resulting from extreme weather events are underemphasized in state- and municipal-level adaptation planning and policymaking**: There is little discussion about the challenges and obstacles transit dependent communities face in dealing with repeated and prolonged transit disruptions that result from extreme weather impacts and even adaptation. These communities require ongoing attention and coping support to deal with adaptive responses of the physical (e.g., new construction) and non-physical variety (e.g., route closures, system shutdowns, etc.), as recurring transit disruptions are likely to weaken their resource capacities and deepen preexisting socioeconomic vulnerabilities.

(3) How have extreme weather events in recent years affected the Philadelphia metropolitan region and its transportation systems?

a. **Extreme weather events in recent years significantly influenced regional economies, physical landscapes and transit infrastructure:** Both the frequency and severity of heavy snowfalls and severe precipitation events resulted in power outages, damaged infrastructure and transit system disruptions throughout the Philadelphia metropolitan region and in other parts of the U.S. Northeast. These impacts significantly reduced people's mobility for days, weeks and months.

(4) What are the managerial and operational circumstances surrounding the Southeastern Pennsylvania Transportation Authority's management of extreme weather?

a. **Historical and geographic circumstances:** An aging, deteriorating and sprawling transit system has complex and complicated management challenges despite weather and climate conditions. Adapting transit infrastructure (e.g., railroad, subway tunnels, etc.) which is locked into urban landscapes is understood by managers to be a daunting task.

b. **Ridership:** The bulk of the agency's ridership can be classified as vulnerable on the basis of its racial and socioeconomic characteristics. The need to offer passenger education was cited by one manager as being critically important to the reduction of extreme weather hazard risk for vulnerable groups such as the elderly.

c. **Capital resources**: Managers suggest that the agency has limited capital resources to keep pace with the increasing incidence of extreme weather events and to invest in adapting infrastructure to climate change. Current resource capacities makes successful adaptation to climate change untenable despite the resilience strategies (e.g., system shutdowns) the agency employs, since weather extremes have grown more intense and frequent in recent years.

d. **Tools and strategies for managing severe weather:** Managers promote the organizational benefits as well as successes of newly developed methods at managing and communicating hazard risks. Nevertheless, commuters' disregard of the agency's alert systems have rendered them ineffective on occasion. Also, managers' knowledge of past events proved unsuccessful at times toward avoiding weather-related equipment and infrastructure damage.

(5) What challenges do managers at the Southeastern Pennsylvania Transportation Authority's face in handling weather extremes and adaptation?

a. **Managerial philosophy:** Close calls with passenger losses resulting from transit operations during extreme weather events showed how managerial philosophy could lead to vulnerable risk and liability. Although managerial philosophy has changed to better account for passenger safety and security, managers' emphasis on liability issues as they relate to operations obscures

attention to vulnerable risks and liabilities related to climate change and adaptation.

b. **External expectations and demand:** The agency faces a potential crisis in the provision of transit service. How and whether the agency will expand its vehicle fleet to compensate for growing ridership demand under normal operating and extreme weather conditions are in question.

c. **Organizational stress:** Increased dependency on contractors who lack reliability has been the result of the growing frequency of weather-related damage to transit infrastructure. This has the potential to create longer disruptions of particular transit systems (e.g., regional rail lines) when contractors seek larger paying jobs elsewhere.

d. **Location of transit infrastructure**: The agency's infrastructure traverses several municipal jurisdictions. This raises critical accountability issues. Which municipality helps to invest in transit system adaptation to climate change? How much? Which municipality is more or less impacted by adaptation?

e. **Condition of transit infrastructure:** Managers emphasize the difference between new and older systems as far as adaptation is concerned. Pointing to deteriorating infrastructure, managers suggest the need for increased

government funding to deal with state-of-good-repair projects which have lacked proper and adequate public support over the years.

f. Capital resources: Managers identify the limitations of its capital resources. An important limitation managers cite as limiting adaptation is government-led spending restrictions on capital projects.

7.3 Theoretical Implications for Transportation Adaptation to Climate Change in Urban Environments

I studied the topic of transportation adaptation to climate change because I wanted to find out how transit managers coped with weather extremes in order to help us better understand their resource challenges, constraints and even opportunities toward climate change adaptation in urban environments. During the early stages of research, newspaper articles were accessed for the purpose of identifying areas of impact throughout the U.S. Northeast. This exercise then led to a review of relevant academic literature to understand various dimensions of extreme weather management and climate change adaptation for a transit agency. However, a limited body of literature on the research topic at hand was discovered through the process. It recognizes the vulnerability of transportation infrastructure to climate change (Chang et al 2010; Jacobs et al 2008; Kirshen et al 2008; Arkell and Darch 2006; Suarez et al 2005), the classification of actors and agents for transportation adaptation (Eisenack 2012), and the physical risk perceptions of actual and potential climate change impacts among transportation professionals (Regmi and Hanaoka 2011;

Lindgren et al 2009). However, this literature does not delve into the particular challenges transit managers face toward climate change adaptation for diverse and large metropolitan areas.

This case study of the Southeastern Pennsylvania Transportation Authority helped to advance the above body of knowledge through an evaluation of adaptation plans, policies, actions and organizational circumstances. The research methods enlisted allowed for the identification of actual factors rather than hypothetical situations that helped toward explaining transit managers' actual and potential successes, failures and even sensitivities toward managing weather extremes and adapting their systems to climate change in the Philadelphia metropolitan region. Here, the study provides for a clear understanding of the obstacles and challenges SEPTA and perhaps similarly situated organizations must overcome across the U.S. For example, government acknowledgement of their circumstances and funding support is crucial in climate change investment decisions, as shown in chapter 6. Chapter 3 showed that transit systems are underappreciated in state and municipal planning and policymaking centering on climate change adaptation. Transit managers convey the need for greater government involvement through funding and policy in order to forcibly address what appears to be an intractable problem. The chapter also demonstrates the complexity of agency decision-making in dealing with actual and potential extreme weather events and adaptation ranging from organizational culture and expectations to neighborhood community and commuter responses. The nature and variety of decision-making factors makes it possible for the generation of uneven impact outcomes

across each of the agency's systems, among various commuter segments, and in places throughout the metropolitan region. As a result, policy interventions need to be instituted that help to sharpen hazard risk assessments and adaptation strategies among transit agencies.

7.4 Policy Implications

As stated earlier, the goal of the project was to visualize what the future held for public transit in the Philadelphia metropolitan region. From this research several implications for policy concerning SEPTA's adaptation efforts are evident:

(1) **State, municipal and transit agency plan integration and implementation should be intentionally and aggressively pursued**. Unlike most states in the study, Pennsylvania's adaptation plan makes specific reference to transit systems. It emphasizes adaptation actions such as intensifying infrastructure inspections, constructing levee systems for railroads located near rivers, and installing pumping stations for subway and trolley systems. However, the state plan lacks specificity on just how these activities are to be made operational and financially supported. Managers speak of existing government mandates that lack adequate funding support. Philadelphia's local climate change plan merely emphasizes greenhouse gas mitigation strategies with no direct mention of adaptation. One interviewee suggested that adapting the agency's transit systems is a regional problem on the basis of what he considered to be "downstream impacts," since adaptation actions

in one part could lead to unintentional and devastating effects in another. Thus, an integral part of a system-wide adaptation program then is the search for and establishment of "common ground" through more intense efforts at adaptation planning and policymaking among all jurisdictions in the Philadelphia metropolitan region. Transit is growing in its importance and significance in the region and governmental plans and policies need to reflect the fact. This burden cannot be shouldered by SEPTA alone. Increasing ridership demand within Philadelphia and throughout its surrounding suburban communities underscores the need for a regional approach to adapting transit to climate extremes.

(2) **Transit adaptation plans and policies, at all levels, must address commuters' socioeconomic vulnerabilities**. Commuters' socioeconomic vulnerability need to be incorporated into hazard risk assessments and adaptation strategies. There are a number of examples of socioeconomic vulnerability assessments in practice which can be modified to fit transit scenarios. Current metropolitan trends such as increased ridership demand and urban development and decline throughout the Philadelphia metropolitan region present complex and complicated challenges to managing weather extremes and adaptation for the agency. Such trends are likely to stretch its transit systems to and beyond their operational and infrastructure capacities should current resource levels remain stagnant, leaving vulnerable commuters to seek alternative and more expensive means of travel. An adaptation program that prioritizes socioeconomic vulnerability as an actual and potential impediment to severe weather management and adaptation progress may likely help

to better establish the case for additional revenue support from public and private sector stakeholders than one which does not.

(3) **Transit adaptation plans and policies need to be written in appreciation of the historical, institutional, physical, social, economic, political and environmental circumstances in which the agency operates from community to community.** Any number and combination of outcomes can and will occur across different metropolitan places and ridership segments from one year or season to the next. Both individual and collective factors identified through the research have important implications for agency effectiveness in managing weather extremes and adapting to climate change. This requires an adaptation program to engage all stakeholders in its development, implementation and continuous updating. This should not be done on a one-time basis. Rather continuous engagement of stakeholders is required, since organizational circumstances, hazard risk and vulnerable conditions change over time and place.

(4) **While they are designed to avert extreme weather impact costs and institutional liability, resilience strategies offer little support and hope in reducing commuters' socioeconomic vulnerability to reoccurring and protracted transit disruptions.** SEPTA values cost- and risk-based management approaches toward dealing with actual and potential weather extremes. The agency's storm management policy emphasizes system resilience and hazard safety. It requires managers to cancel individual or system-wide route service

"before conditions force a halt to service." Social media (e.g., Twitter) and formal news outlets are then used to inform commuters about the decision in advance of at least an hour. Likewise, managers insist that the agency's venture into adapting its Norristown – Manayunk regional rail line to riverine flooding will be effective by utilizing a "comprehensive approach" that has the objective of minimizing "downstream impacts." However, the combination of seasonal weather fluctuations and their surprises, their short- and long-term impacts, commuting behavior, and the complex and complicated nature of urban decline and development across the Philadelphia metropolitan region requires additional safeguards for surprises. Researchers and policymakers need to design safety net interventions that help to address what SEPTA's storm policies and adaptation actions overlook in its aim toward reducing institutional costs and liability.

(5) **Public education must be an integral theme of transit adaptation policy and practice in the Philadelphia metropolitan region.** Managers' observations of commuting behavior during extreme weather and other crisis events legitimize the need for neighborhood- and institutional-based educational forums that detail the agency's risk management and climate change adaptation efforts. Being mindful that transit disruptions have become more frequent in some instances, such an intervention allows commuters of all types to build their adaptive capacities to better cope with their short- and long-term loss in urban and suburban situations.

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7.5 Study Limitations

The study has limitations the researcher wishes to resolve through future research opportunities. First, the sample size of managers interviewed is low. There are two reasons for this. This exploratory project demanded focused attention on the nuances of how one metropolitan transit agency dealt with severe weather events and adaptation. Adding more agencies would have clouded the results. Attempts were made to reach out to other transit agencies in the study region. However, their lack of interest toward participating in the study was perhaps due to political and media scrutiny surrounding their management of severe weather events and associated failures. Second, individual and focused group meetings with commuters are believed to enhance the study to understand their responses to weather-related management policies and perceptions of adaptation activities. First-hand knowledge of commuters' encounters with transit loss and disruption resulting from not only severe weather events but also proposed adaptation projects is an invaluable addition but their inclusion was beyond the scope of the study.

7.6 Future Research

Transportation adaptation to climate change is a vital yet understudied topic in hazards, environmental change, urban and economic geography research fields. This dissertation set out an ambitious goal to help advance the small body of knowledge that does exist. The effort revealed several research paths geographers and other social science researchers

interested in the intersections of climate, society, and transport can explore. These areas of research are as follows:

(1) **Transit commuters' conceptualizations of extreme weather risk and their rights to public transportation warrants investigation**. Study participants cited instances in which commuters were either unaware or ignored the agency's decision to suspend transit services as a result of extreme weather conditions. Research is needed on the factors that influence commuter response to operational transit system changes due to extreme weather events. Researchers have employed quantitative methods to analyze commuters' modal choice decisions during inclement weather. They not only have distanced themselves but also their subjects from the many issues they face in extreme weather crises while utilizing transit as a result. A qualitative approach will allow for an engaging analysis of commuters' mechanisms for coping. Moreover, there is the need for participatory vulnerability assessments whose aim would be to better inform hazard risk management practices and climate change adaptation programs.

(2) **Transit ommuters' mobility experience during the course of extreme weather events need to be documented**. This topic has been investigated in relationship to air travel disruption resulting from the eruption of Eyjafjallajökull in Iceland in 2010. However, it centers on the experiences of global travelers whose vulnerabilities likely contrast with that of transit-dependent persons in urban communities. What is the mobility experience of transit-dependent persons and

how might this differ across transit systems during the course of extreme weather events (e.g., bus, rail, trolley, subway)?

(3) **A deeper understanding of the attitudes, values and beliefs of those with power and authority over transit systems toward current and future extreme weather events is needed**. Participants in the study expressed the idea that individual transit systems have particular vulnerabilities to extreme weather on the basis of their location, design and use capacity. However, this research did not fully capture the nonmaterial value managers ascribed to individual systems and communities. Also, it gave little attention to corporate, political and community stakeholders. This may have important policy implications over which transit systems and communities receive more or less attention with regards to climate change adaptation.

APPENDICES

APPENDIX A

Listing of U.S. State Adaptation Planning Materials for Content Analysis

State	Year	Document
AK	2010	Alaska's Climate Change Strategy: Addressing Impacts in Alaska: Final Report Submitted by the Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet http://www.climatechange.alaska.gov/aag/docs/aag_all_rpt_27jan10.pdf
CA	2009	2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order S-13-2008 http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf
CT	2011	Connecticut Climate Change Preparedness Plan: Adaptation Strategies for Agriculture, Infrastructure, Natural Resources and Public Health Climate Change Vulnerabilities http://ctclimatechange.com/index.php/draft-preparedness-plan/
KY	2011	Action Plan to Respond to Climate Change in Kentucky: A Strategy of Resilience http://fw.ky.gov/kfwis/stwg/2010Update/Climate_Change_Chapter.pdf
ME	2009	Climate Change and Transportation in Maine http://www.maine.gov/mdot/env/documents/pdf/ClimateChangeandTransportationinMaine-Final.pdf
MD	2011	Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase II: Building societal, economic, and ecological resilience http://www.dnr.state.md.us/climatechange/climatechange_phase2_adaptation_strategy.pdf
MA	2011	Massachusetts Climate Change Adaptation Report http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf
NY	2011	Mainstreaming Climate Change Adaptation Strategies into New York State Department of Transportation's Operations: Final Report http://www.utrc2.org/publications/mainstreaming-climate-change-adaptation-strategies-new-york-state-department
OR	2010	The Oregon Climate Change Adaptation Framework http://www.oregon.gov/ENERGY/GBLWRM/docs/Framework_Final_DLCD.pdf

APPENDIX A

Continued Listing of U.S. State Adaptation Planning Materials for Content Analysis

State	Year	Document
PA	2011	Pennsylvania Climate Adaptation Planning Report: Risks and Practical Recommendations http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-82988/7000-RE-DEP4303%20combined%20report.pdf
RI	2012	Adapting to Climate Change in the Ocean State: A Starting Point http://www.rilin.state.ri.us/Reports/Climate%20Change%20Commission%20Prog%20Report%20Final%2011%2015%2012%20final%202.pdf
VA	2011	Summary of Natural Resources/Shoreline Adaptation Strategy Recommendations of the Virginia Commission on Climate Change http://www.wetlandswatch.org/Portals/3/WW%20documents/Adap_Strat_adopted_VCCC_062109.pdf
WA	2012	Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy https://fortress.wa.gov/ecy/publications/summarypages/1201004.html
WI	2011	Wisconsin's Changing Climate: Impacts and Adaptation http://www.wicci.wisc.edu/report/2011_WICCI-Report.pdf

APPENDIX A

Listing of U.S. Municipal Adaptation Planning Materials for Content Analysis

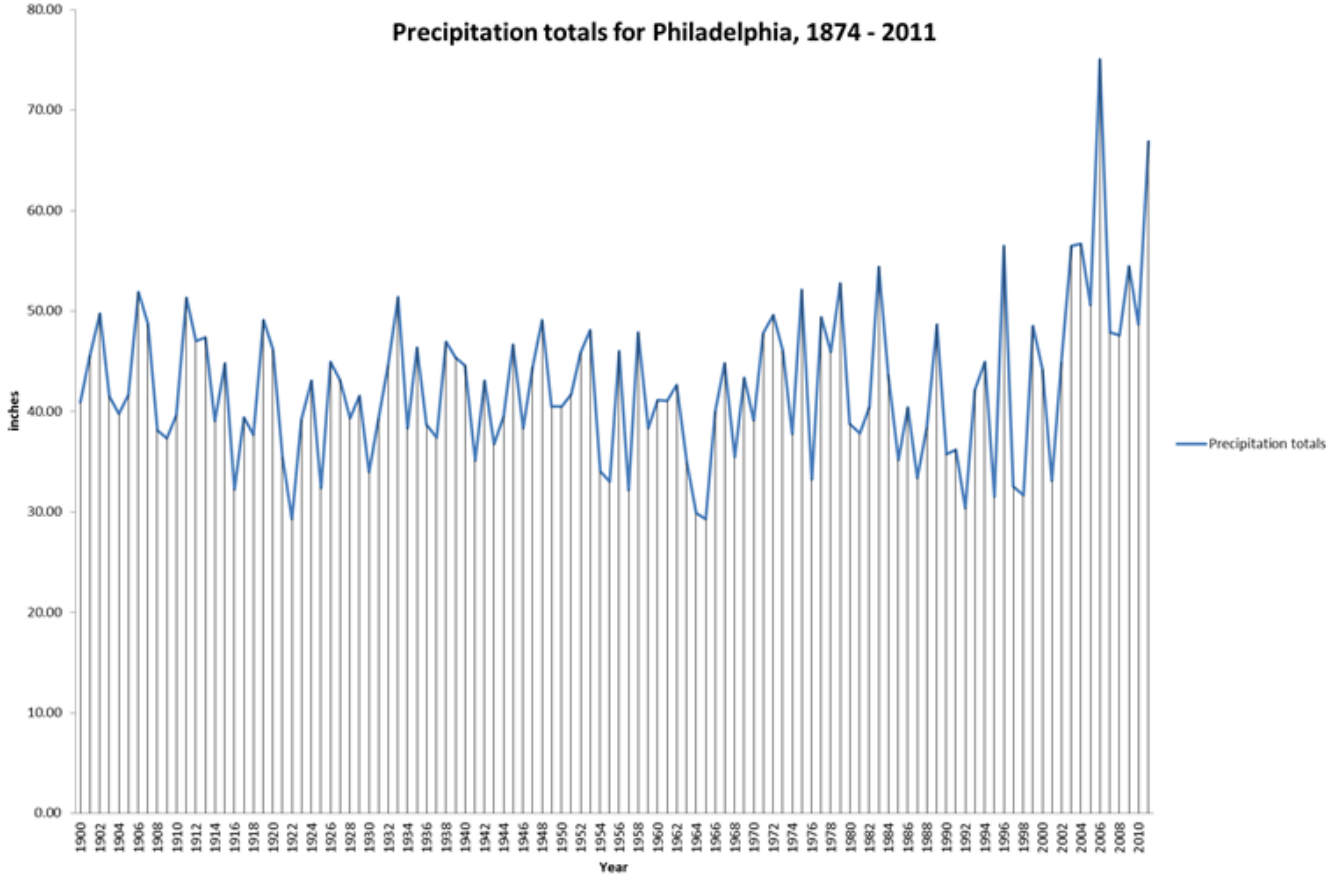
State	Year	Document
AK	2008	Recommendations Report to the Governor's Cabinet on Climate Change: Final Report from the Immediate Action Working Group http://www.climatechange.alaska.gov/docs/iaw_rpt_17apr08.pdf
CA	2010	Taming Natural Disasters: Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area http://quake.abag.ca.gov/wp-content/documents/ThePlan-Chapters-Intro.pdf
CA	2011	Integrated Strategies for a Vibrant and Sustainable Fresno County http://www.lgc.org/adaptation/fresno/docs/Integrated_Strategies_for_Vibrant_Sustainable_Fresno_County_3011.pdf
CA	2011	Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf
CA	2012	Sea Level Rise Adaptation Strategy for San Diego Bay http://www.icleiusa.org/static/San_Diego_Bay_SLR_Adaptation_Strategy_Complete.pdf
CA	2011	City of Santa Cruz Climate Adaptation Plan http://www.icleiusa.org/action-center/planning/Santa_Cruz_Climate_Adaptation_Plan.pdf
DE	2011	The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan http://www.deseagrant.org/sites/deseagrant.org/files/attachments/Lewes%20Hazard%20Mitigation%20and%20Climate%20Adaptation%20Action%20Plan.pdf
FL	2011	City of Punta Gorda Adaptation Plan http://www.cakex.org/sites/default/files/Punta%20Gorda.pdf

APPENDIX

A Continued Listing of U.S. Local Adaptation Planning Materials for Content Analysis

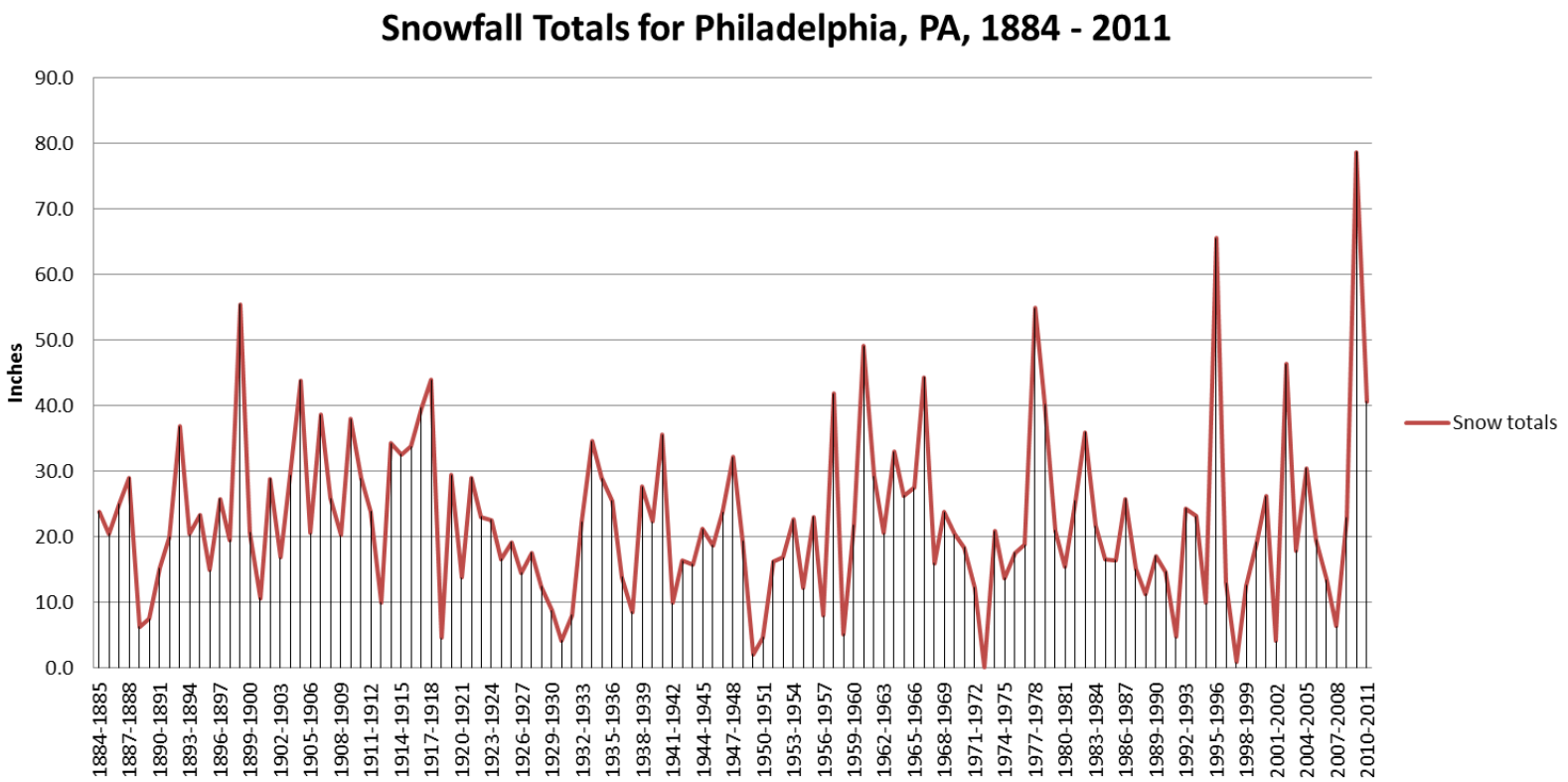
State	Year	Document
FL	2012	A Region Responds to a Changing Climate: Southeast Florida Regional Climate Change Compact Counties http://southeastfloridaclimatecompact.org/pdf/Regional%20Climate%20Action%20Plan%20FINAL%20ADA%20Compliant.pdf
MA	2012	Buzzards Bay, MA: Planning For a Shifting Shoreline and Coastal Storms http://www.buzzardsbay.org/newccmp/newccmp-shorelines.pdf
WA	2010	Swinomish Climate Change Initiative Climate Adaptation Action Plan http://www.swinomish-nsn.gov/climate_change/Docs/SITC_CC_AdaptationActionPlan_complete.pdf

APPENDIX B



Source: National Weather Service

APPENDIX B



Source: National Weather Service

APPENDIX B Total monthly precipitation for City of Philadelphia (rainfall inches), 2001 – 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	3.37	3.11	2.09	1.74	5.36	5.32	4.18	2.14	2.95	2.77	4.02
February	3.81	0.52	7.29	2.71	3.28	1.37	1.74	5.88	0.98	5.72	2.70
March	6.29	4.98	4.74	4.00	3.71	2.60	2.95	4.39	1.38	7.55	4.50
April	1.67	2.64	3.27	7.02	6.62	4.25	10.04	2.46	4.34	3.85	6.41
May	3.41	4.21	5.80	2.55	1.27	11.79	4.08	4.76	4.76	2.61	2.57
June	4.92	3.92	5.92	3.77	3.57	17.58	4.04	3.43	5.46	2.15	2.43
July	1.42	2.71	1.59	9.97	5.80	5.29	2.54	5.70	4.71	8.33	3.26
August	1.92	3.77	3.58	7.76	3.05	7.64	4.00	1.69	9.38	1.08	16.70
September	2.19	3.29	6.30	8.10	1.09	6.06	1.93	4.97	3.61	6.77	12.00
October	0.71	6.09	5.26	2.19	10.40	5.75	5.46	3.21	6.21	2.43	2.94
November	0.88	5.04	3.99	3.19	3.33	4.85	1.93	4.21	2.44	3.15	4.39
December	2.55	4.61	6.68	3.67	3.15	2.58	4.96	4.77	8.23	2.25	5.00
Total inches	33.14	44.89	56.51	56.67	50.63	75.08	47.85	47.61	54.45	48.66	66.92

Source: NOAA

APPENDIX B

Heavy snowfalls in Philadelphia and surrounding counties

Day	Date	Month	Year	Amount
Tuesday	17*	January	1978	4.4
Thursday	19*	January	1978	3.9
Friday	20*	January	1978	9.3
Monday	6*	February	1978	12.4
Tuesday	7*	February	1978	1.2
Monday	19	February	1979	13.9
Saturday	13*	March	1993	5.4
Sunday	14*	March	1993	10
Sunday	7*	January	1996	27.6
Monday	8*	January	1996	3.1
Saturday	3	February	1996	6.5
Saturday	17	February	1996	7.5
Saturday	30	December	2000	9
Thursday	22	February	2001	7
Tuesday	5	February	2002	7
Wednesday	15*	January	2003	2
Thursday	16*	January	2003	16
Friday	17*	January	2003	2.7
Sunday	20	December	2009	16.1
Saturday	6*	February	2010	9.8
Monday	7*	February	2010	9.6
Wednesday	10*	February	2010	11.3
Thursday	11*	February	2010	9.1
Monday	27	December	2010	12.9
Thursday	27	January	2011	11.8

Sources: The Franklin Institute, Philadelphia/Mt. Holly, NJ Weather Center, Philadelphia International Airport, National Climate Data Center COOP Reports

*Accumulations increase and persist for 3 or more days past initial snowfall observation

APPENDIX C

Engineering questions

(1) How has SEPTA's engineering division been coping with the most recent severe weather events (e.g., Hurricane Iren, Tropical Storm Lee, etc.) that have been affecting the Philadelphia metropolitan region?

(2) What kind(s) of problem(s) has heat, cold weather, ice, and snow presented to the agency's infrastructural assets in the city and the surrounding suburbs? How extensive is the problem(s) geographically, by mode, by method of conveyance (e.g., tunnel, rail, street, highway)?

(3) Do you envision those problems worsening or lessening over time and place and what are the factors involved in such transitions or changes?

(4) From your standpoint, to what extent do the agency's strategies for severe weather involve adaptation such as assessing current and future vulnerabilities, technical fixes for extreme situations (e.g., track buckling, air conditioning in tunnels, etc.), impact studies (e.g., heat influence on passengers and modes), etc.?

(5) What has been the most impactful severe weather event on SEPTA's engineering assets to date?

(6) How does engineering work with or assist other agency divisions in planning and preparing for severe weather events? How does this take shape?

(7) Is climate change (severe weather uncertainty and ambiguity) an issue that poses concerns for engineering operations as it relates to maintenance, repair and new construction?

(8) The Federal Transit Administration (FTA) in its 2011 report titled, "Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation" claims that there are "four broad categories of overall adaptation strategies" for transit agencies that include: (1) maintenance and management; (2) strengthening and protecting; (3) enhancing redundancy; and (4) abandoning infrastructure in extremely vulnerable areas. Within the region, what constraints, challenges and opportunities might such strategies pose to the agency and its patrons from an engineering standpoint? Is engineering actively involved in any of these strategies? If so, what are they and what have been their outcomes?

(9) The FTA also lists the potential and actual impacts of severe weather and climate on transit agencies goals that are: (1) safety; (2) state of good repair; (3) cost containment; (4) regional mobility; and (5) service to transit dependent populations. What benefits and costs might transit agency/system adaptation strategies initiated by engineering yield for the agency (e.g., asset management,

construction, capital investment, etc.) as well as its patrons should it perform one, a combination of several, or all four?

(10) How does engineering define success in its approach or strategies toward severe weather events? Specifically, what are the measures of its success and how does the agency go about capturing them?

Operations questions

(1) What has been your experience with severe weather while employed at the agency?

(2) Broadly speaking, how would you define the agency's operational assets?

(3) Does that definition have congruency or shared agreement across the agency?

(4) What kind(s) of problem(s) is heat, cold weather, ice, and snow for the agency's operational assets?

(5) Have those problems increased or decreased over time? Have those problems increased or decreased across different parts of the transit system? What occurred to increase or decrease the problem(s) over time and place?

(6) Has SEPTA developed an official plan to adapt its 'hard' and 'soft' operational assets to climate change? If so, what role(s) did operations play in the effort? If not, how would you envision your division's contribution to achieving such an objective?

(7) From an operational standpoint, to what degree or extent have the agency's adjustment strategies for severe weather been done with foresight and planning whether in the past or present?

(8) How does the agency go about assessing the vulnerability of its operational assets to severe weather events? Is this a systematic process?

(9) Does the agency assess the vulnerability of its operational assets to severe weather events through internal audits, outside consultants, or a combination of both?

(10) Do different findings emerge as a result of who conducts the vulnerability assessment? If this is the case, what factor(s) contribute to this outcome?

(11) To what extent or degree are vulnerability/adaptation assessments integrated with the agency's asset management program?

(12) What has been the most impactful severe weather event on SEPTA's operational assets?

(13) If any, what operational conflicts exist between ensuring passenger safety and making SEPTA'S transit system resilient during the course of severe weather conditions?

(14) What are the potential threats and weaknesses to SEPTA's operational assets during the course of severe weather events now and in the future?

(15) How does your division work with other divisions across the agency to assess the vulnerability of its transit system to severe weather?

(16) How does your division work with other divisions across the agency to enhance the resilience of its transit system to severe weather?

APPENDIX D

RUTGERS
NEW BRUNSWICK

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February 18, 2011

Richard Maloney
Director
Office of Public Affairs
SEPTA
1234 Market Street
Philadelphia, PA 19107

Dear Mr. Maloney:

This letter comes to you as a request for SEPTA's participation in a doctoral dissertation research project in the field of geography that serves to understand the performance of the agency's snow management policies and procedures across the Philadelphia metropolitan region.

This case study topic emerged from my graduate studies and research in natural hazards, climate change and urban development. The most recent news coverage of snowstorm impacts on transport systems in the U.S. and northern Europe also influences this work. Examining Philadelphia's experience in building transport system resilience given the overarching context of severe weather events, fiscal crises and their combined impacts is the principle goal of this dissertation research.

A mixed methods research protocol is employed in this study. Learning about key officials, planners, managers and operators' experiences in implementing the agency's newly adopted snow storm policy represents a quarter of the project. The other three quarters involve archival research on the natural hazard experiences of SEPTA and its predecessors; qualitative analyses of citizens' experiences with and perceptions of severe weather policies and procedures; and a metropolitan population vulnerability assessment using GIS.

This work means a great deal to me. I am a native Philadelphian. SEPTA has, over the years, played an important role in my personal growth and professional development by transporting me to Rutgers; my jobs at the City of Philadelphia's Commerce Department and the University of Pennsylvania; and my classes at West Chester University, Temple, Roman Catholic High School, and St. Elizabeth's Elementary School before its closure. Thus, the time that I am devoting to this research extends back to my formative years as a child and young adult.

RUTGERS
NEW BRUNSWICK

The opportunity to meet with you or your representative to discuss my research in further detail would be deeply appreciated. Thank you for your attention to this request. I can be reached at (215) 760-2411 or markba@eden.rutgers.edu to schedule a date and time that is most convenient for you.

Warmest regards,

Mark Barnes
PhD Candidate
Department of Geography

c: Robert Lake, PhD
Robin Leichenko, PhD, Dissertation Advisor
James Mitchell, PhD
Robert Noland, PhD

APPENDIX D

1234 Market Street
Philadelphia, PA 19107-3780

Southeastern Pennsylvania Transportation Authority
Safety • Service • Continuous Improvement

May 12, 2011

James Cavazzoni, PhD
Sponsored Programs Administrator
Office of Research and Sponsored Programs
Rutgers, The State University of New Jersey
ASB III, 3 Rutgers Plaza
New Brunswick. NJ 08901

Dear Dr. Cavazzoni:

Please consider this letter SEPTA's official and enthusiastic approval and support for the pending research by Mr. Mark Barnes.

Severe weather has historically presented enormous managerial and technical challenges for a large urban public transportation system such as SEPTA, which is responsible for providing reliable, safe and efficient transportation for approximately one million customers each day.

Significant weather-related interruptions of public transit service can – and do – directly impact the lives and livelihoods of the citizens of our region, and its economic well being.

Mr. Barnes' preliminary research has focused on how dramatically relatively new technologies such as GPS and Social Media have enabled SEPTA to vastly improve its management of transportation systems operations during severe weather.

The impact of these technologies cannot be understated; it is historically unique to our industry, and promises great benefits to SEPTA and countless transportation systems world wide.

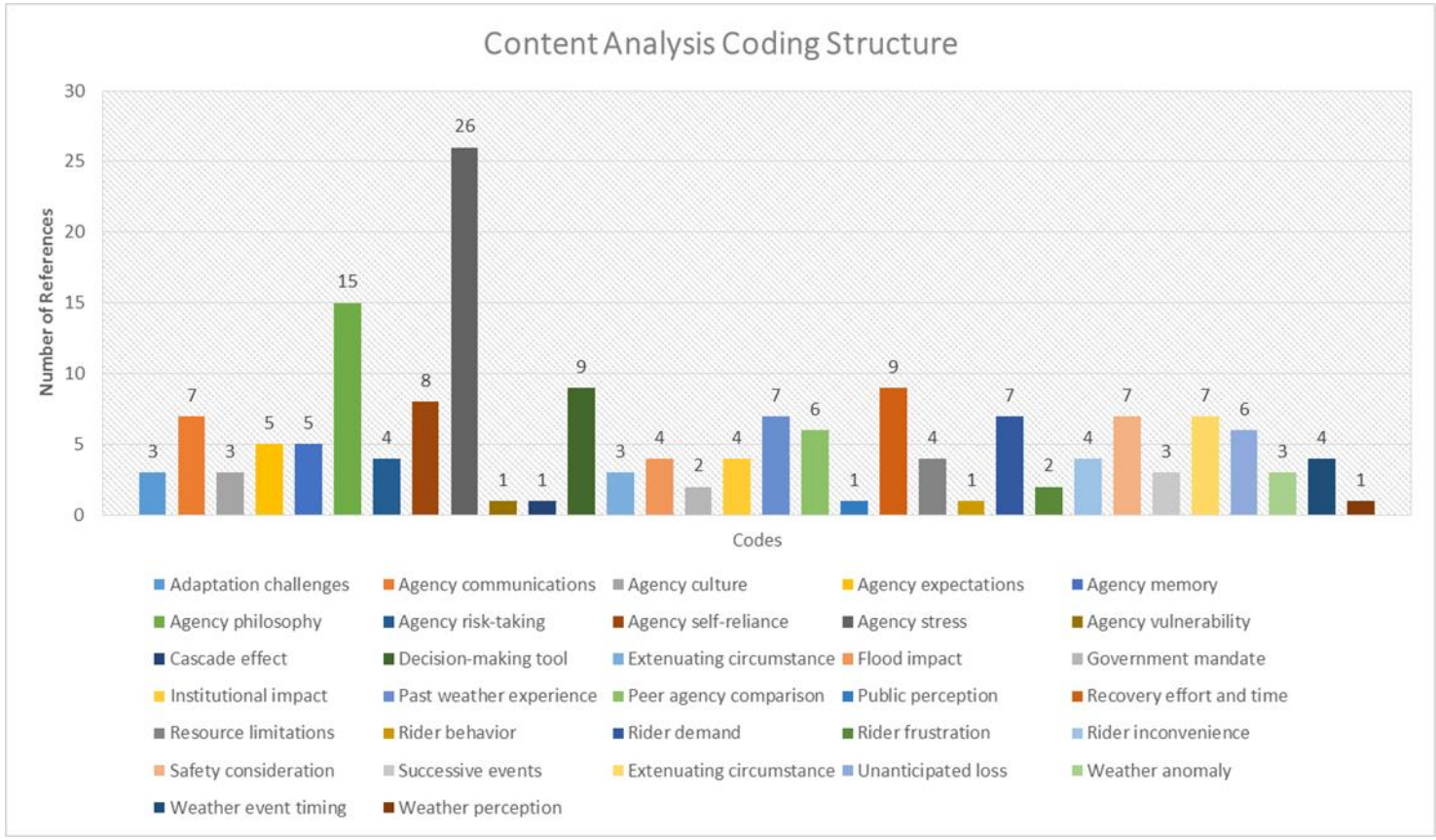
Therefore, SEPTA enthusiastically supports Mr. Barnes' research. Indeed, we are anxious to learn and benefit from the results of his academic studies.

Please do not hesitate to contact me directly with any questions you may have concerning SEPTA's participation in this important research.

Sincerely,

Richard Maloney
Director: Public Affairs & Marketing
(215) 580-7403
rmaloney@septa.org

Appendix E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Adaptation challenges
Agency communications
Agency culture
Agency expectations
Agency memory
Agency philosophy
Agency risk-taking
Agency self-reliance
Agency stress
Agency vulnerability
Cascade effect
Decision-making tool
Extenuating circumstance
Flood impact
Government mandate
Institutional impact
Past weather experience
Peer agency comparison
Public perception
Recovery effort and time
Resource limitations
Rider behavior
Rider demand
Rider frustration
Rider inconvenience
Safety consideration
Successive events
Extenuating circumstance
Unanticipated loss
Weather anomaly
Weather event timing
Weather perception

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