

Adaptive Mobility for Weather Extremes: The Case Of Public Transit Management In

The Philadelphia Metropolitan Region

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ABSTRACT

Public transit is a vital resource component of urban mobility around the globe. Yet, its effective functioning is routinely undermined by powerful weather extremes that exact significant tolls on its transport modes (e.g., bus, train, etc.) and infrastructure (e.g., bus depots, subway tunnels and stations, etc.). Transport disruptions and losses resulting from impactful weather hazards not only hamper local and regional economies, but also have severe consequences for the financial health and social wellbeing of vulnerable groups. Recent research has documented the physical exposures of transport systems to weather extremes and people's social vulnerabilities in metropolitan locales. However, the management of those systems under extreme weather stress and their adaptation to climate change has not been a healthy area of research within any field of social science research.

This paper presents qualitative findings from a case study on the mobility policies and practices of extreme weather mitigation and adaptation for the major public transit agency that serves the Philadelphia metropolitan region. Its aim is to understand the causes, consequences, challenges, and constraints of transit managers' real-life mitigation and adaptation (re)actions to past and anticipated weather extremes. Interview findings demonstrate that managers' decisions about the utilization of transportation assets relative to weather extremes are richly imbedded in historical legacies and today's socio-political and economic environments. Such decisions often produce inadvertent mobility wins and losses among metropolitan places and peoples. The implications of the interview results are then situated in a broader discussion of mobility and public transit adaptation to climate change.

1. Introduction

In U.S. metropolitan regions today, commuters who rely on mass transit must often adjust their travel plans whenever and wherever weather extremes incapacitate their effective functioning. This practice will become a more common yet much challenging way of living for vulnerable commuters with high transit use dependencies as climate change continues to unfold. With the notion that extreme weather impacts on mass transit systems influence the mobility and financial health of commuters; and the social and economic wellbeing of the places in which they live, work and recreate, geographic and spatial lenses are needed to examine whether and how they adjust to vulnerable states of being resulting from weather-related service disruptions and facility loss.

Arguably, mass transit is the most affordable and only means of travel for work, shopping, education, healthcare, and so on for vulnerable transit commuters. Their transit dependencies place them at high risk of very profound economic, social and political hardships as a consequence when weather extremes threaten the sustainability of mass transit systems in metropolitan centers (Bartling 2008; Tiessen 2008; Litman 2005).

A gaping hole in transport and environment scholarship relating to weather, climate, and society exists and persists. Actual and anticipated (non)meteorological impacts on transit systems are well documented (Chang et al. 2010; Jacobs et al 2008; Kirshen et al. 2008; Arkell and Darch 2006; Call 2005; Suarez et al 2005; Changnon 1996; Rooney 1967). Modal choice decision-making among commuters amid fair and inclement weather patterns have been modeled (Stover and McCormack 2012; Guo et al 2009; Kalkstein et al. 2009; Khattak and DePalma 1997). All that we have at the moment is anecdotal

evidence of transit commuter mobility during and after transit system disruptions and facility loss resulting from extreme weather events (Kaufman et al. 2012; Zimmerman and Faris 2010). Little is known about how transit managers conceptualize extreme weather risk and make adjustments to weather crises in urban environments. Also, we know nothing of how transit commuters are factored into managerial response plans. Such knowledge is necessary toward changing the effectiveness and success of adapting transit systems to climate change for urban mobility sake.

The Southeastern Pennsylvania Transportation presents an opportunity to conduct a case study of managerial conceptualizations and actions toward transit system adaptation to climate change trends that are occurring now. In recent years the agency has instituted a storm policy unlike any one in previous history due to reoccurring storm impacts. It is among the largest transit system agencies in the U.S. Also, it has taken proactive measures to participate in the Federal Transit Administration's Transportation Adaptation to Climate Change Pilot Program albeit before this study was conducted. The sections to follow focus on the context of the case study, a case study description, method, case analysis, and conclusion.

2. Case-study context: transport and ridership vulnerability to weather extremes

Transportation adaptation to climate change has risen in importance among planners, policymakers, advocates, and social science researchers in recent years (BPC 2009; TRB 2008). In fact, the recently released Intergovernmental Panel on Climate Change report (2014) recognizes the pressing need to adapt to current and future climate change

impacts while outlining potential and actual constraints and limitations in urban areas and for different economic sectors. For mass transit systems, adaptation responses such as route closures, service cutbacks, new construction, facility abandonment and so on have been offered as necessary solutions toward reducing extreme weather event and sea-level rise exposures (FTA 2011). The societal implications for racial and income inequality and environmental justice that are imbedded in adapting transit systems to climate change have yet to catch researchers' sociological and geographical imaginations, no less (Eisenack 2012; Regmi and Hanaoka 2011; Lindgren et al. 2009). Today U.S. transit agencies are adopting and implementing adaptation strategies with little government guidance, no regulation, and meager capital resources. Also, there is a lack of common knowledge and understanding about the actual and potential impacts of transit agencies' adaptive responses on commuters and communities across metropolitan space (Barnes 2014). This is problematic because transit systems are locked into the built and natural landscapes of various urban and suburban community types; and they crisscross their jurisdictional boundaries. Therefore, possible "downstream impacts" from adaptive responses demands investigation since those implemented in one part of the system hold real potential for producing unintended consequences in another.

Fundamental to lessening threats and impacts from adaptive responses is the coordination of purposeful regional partnerships. Cross-jurisdictional governance that account for conscientious investments in people and communities is essential toward the production of equitable adaptation (Marsden and Rye 2010; Gerber and Gibson 2009). Goal fulfillment requires knowledge about transit stakeholders' conceptualizations and priorities relating to vulnerable transit commuters and their communities in adaptation

planning, policy and management schemes. This area of urban sustainability research is crucial on the basis that never before have the fates of metropolitan centers, their citizens, and the transit systems that link them all been as intertwined as they are today due to widening inequalities resulting from multi-scalar economic, social, political, and environmental processes (Adams et al. 2008; Leichenko and O'Brien 2008).

In light of the above, extreme weather transit disruption and the actual and perceived impacts of adjustment on vulnerable commuters in metropolitan centers of the U.S. Northeast Region demands a closer look for the following reasons: (1) millions of urban and suburban residents and workers depend on mass transit as a primary source of travel and safety net or lifeline (AHUA 2006); (2) mass transit is geographically fixed and traverse and establish connections between a broad range of social, economic, physical and political landscapes at multiple spatial scales (Niedzielski et al. 2012); (3) mass transit has serious state-of-repair problems that climate change exacerbates (Ruth and Coelho 2007); the social and economic competitiveness of cities is largely dependent on functional mass transit (Clark 1958); (4) mass transit demand is rising (Buehler 2009; Woodside 2008); mass transit sits often at the center of discussions on race, class, inequality, and environmental justice in urban society (Sen 2008; Milligan 2007; Sanchez and Brenman 2007; Bullard 2003); and those that highly depend on their effective functioning are at greatest risk of transit disruption and loss (Glaeser et al. 2008; Pucher and Renee 2003).

3. Case study: The Southeastern Pennsylvania Transportation Authority, Extreme Storm Events, Response, and Outcomes

The Southeastern Pennsylvania Transportation Authority (SEPTA) is the 5th largest transit system in the U.S. in unlinked passenger trips and miles traveled according to recent reports (APTA 2013). Interestingly enough, it has handled direct transit service to residential and business communities throughout the City of Philadelphia and its surrounding metropolitan region for a half-century or more. However, despite the modern additions made to its network system of regional transfer centers and local station hubs, transport infrastructure (e.g., railroads, subway tunnels, bridges, etc.), vehicle fleets (e.g., bus, trolleys, etc.), and dispatch control units by the agency in recent years much of what it maintains today is a clear and solid reflection of a legacy of management failures and bankruptcy demise its corporate predecessors left behind.

In 1963, the Commonwealth of Pennsylvania fostered SEPTA's incorporation through a legislative act of state intervention. After its golden years between the early 1900s and start of World War II, the networked system of passenger rails the Pennsylvania Railroad (PR) and Reading Company (RDG) built and maintained in the state's jurisdictional boundaries and beyond fell into sharp decline. Contributing to the system's ruin was the combination of shifting consumer demand, urban and suburban development transition and change, enterprising competitors, managerial ineptitude, unused and aging infrastructure, taxes, merger incompatibilities, and more. The Commonwealth's legal action was motivated by the threat of losing its portion of the rail system that connected high-demand commuter hubs in Philadelphia, Pittsburgh, Baltimore, New York, Chicago,

the New Jersey shore, and other places. Included in SEPTA's original scope of work were ensuring PR and RDG conducted proper and effective stewardship over government subsidies designed to help return the passenger rail network to its early prominence as a positive force of business development; and assisting the Southeastern Pennsylvania Transportation Compact, an organizational precursor to what is presently known as the Delaware Valley Regional Planning Commission, with dealing with transportation issues of a regional nature.

In just a few short years of the Commonwealth's legislative order, between the late 1960s and early to mid-1970s, mergers and acquisitions undertaken by PR, RDG, and other notable and sizeable companies such as Conrail resulted in business bankruptcies. Not only did receivership agreements channel those companies' insolvent possessions directly to SEPTA; but the transit agency moved also to acquire the bus, trolley, and heavy rail (e.g., EL and subway) assets and routes of the Philadelphia Transportation Company and Philadelphia Suburban Transportation Company in 1968 and 1970, respectively.

Today SEPTA operates a so-called legacy transit system, which is the biggest in the Commonwealth of Pennsylvania serving the Philadelphia metropolitan region. The region is defined by media coverage extent for the purposes of this article, and is inclusive of counties in southeastern Pennsylvania, southern New Jersey and northern Delaware. Representing Pennsylvania are Bucks, Chester, Delaware, Montgomery, and Philadelphia counties. In New Jersey, the region consists of Camden, Burlington, Gloucester, Mercer, and Salem counties. New Castle, DE concludes the list. However,

SEPTA provides direct transit service only to Bucks, Chester, Delaware, Montgomery, Philadelphia (also the City of Philadelphia), Mercer, and New Castle counties (Figure 1). There are 196 fixed transit routes in each cardinal direction that ties 869 square miles of diverse cultural, economic, political and physical geographies tightly together, creating challenging circumstances for SEPTA's managers to uniformly and effectively plan for, respond to, and recover from weather-induced system stress in a consistent manner.

Figure 1 about here

In ridership terms, an estimated 3.3 million persons utilize every facet of the transit agency's multi-modal system on a near annual basis. SEPTA's ridership is reflective of the social and class divides that are customary to metropolitan society. Figure 2 shows the results of a Customer Satisfaction Survey the transit agency conducted in 2008, which it says is 'typical' of its loyal consumer base. In 2012, the agency realized unprecedented ridership growth as shown in Figure 3. Managers at SEPTA suggest that the apparent rise in public transit demand is indicative of nationally observed trends (Woodside, 2008). That being the case, ridership diversity and volume likely makes ordering, organizing and recovering transit service a difficult proposition for SEPTA and similarly situated agencies to realize when extreme weather strikes. I now turn to the managerial responses of SEPTA to extreme weather events in recent years and their related outcomes in the following subsections.

Figure 2 about here

Figure 3 about here

3.1 The 2009 – 2010 Winter Season

On December 19, 2009, SEPTA's service territory was visited upon by a Nor'easter with blinding whiteout conditions. The snowfall amount over a two-day period reached 23.2 inches in Philadelphia County according to meteorological observations, just 4.4 inches shy of the record total that had been established on January 7, 1996. In other counties, snowfall amounts ranged from 12 to 23 inches in measured volume. In slightly over a week's time—before municipal snow removal efforts could return the area to less hazardous operational conditions—new storms brought snowfall accumulations of up to 14 inches to add stress to SEPTA's beleaguered transit system. In what later would be classified as a 'historic' winter event the succession of snowstorms from December 2009 to February 2010 caused equipment loss and dramatic declines in the agency's on-time service performance. Consequently, SEPTA, which traditionally operated the full range of its system's compliments at maximum strength until snow impacts resulted in vehicular breakage and impassable thoroughfares and railways, took unprecedented action in conducting its voluntary shutdown. On, February 5, 2010, the day the agency's new storm policy was publicly announced and implemented, managers cited passenger and employee safety concerns, technological innovations for monitoring the movement of its vehicle fleet, and cost savings as the complete rationale for the decision to force an intentional halt. Transit passengers unaware of SEPTA's service interruption plans were left stranded at vehicle berth locations while en route to their destinations that day.

3.2 Hurricane Irene, 2011

Hurricane Irene made landfall in the Philadelphia metropolitan region on August 27, 2011. Preceding Irene was one of the wettest summers in the region's recorded meteorological history, which managed to help intensify floodscape conditions for the Delaware and Schuylkill rivers, urban streams, creeks, and storm water drainage systems. Tropical Storm Lee worsened flood matters in the days following Irene's departure. Flood stage heights for many components of the area's fluvial system crested well beyond their containment capacities. Residential, commercial and industrial districts throughout the region became inundated as drainage systems failed and overflowed. In the City of Philadelphia, Irene broke the standing record for precipitation in August after releasing 19.31 inches of rain. She generated heavy wind velocities of 50 to 70 mph. Combined flooding and steep wind gradients produced widespread damage to the tree canopy and lifeline infrastructure of energy lines, streets, and railways throughout SEPTA's service territory. PECO (also known as the Philadelphia Electric Company) and SEPTA work crews took days and weeks to restore energy lines and transport infrastructure to functioning use capacity. Recovery wait times in urban and suburban places were sharply felt by transit commuters and business owners as a result. In the Philadelphia metropolitan region, estimated damage costs from Irene totaled \$1.1B.

Locational fates and operational circumstances factored remarkably into the damage and costs that Hurricane Irene distributed across SEPTA's regional rail system. Storm precipitation and winds dramatically compromised the physical integrity of the region's railroad tracks and rail embankments by washing away their support structures. The result

was widespread transit disruption. Poorly protected signal equipment caught ablaze due to water intrusion. Energy transmission lines used to motor rail cars collapsed from toppled trees. SEPTA's Manayunk – Norristown Regional Rail Line, one of the agency's most highly prized and used rail routes among suburban commuters, encountered extreme flooding along the stretch of track abutting the Schuylkill River. The Assunpink Creek in Mercer County, a tributary of the Delaware River that sits several hundred feet away from the Trenton Transit Center, inundated its tracks and station platform. The Center connects SEPTA commuters with trips originating in Pennsylvania to New Jersey and New York and vice versa. Managers' disregard for Irene flood warnings and inability to coordinate vehicle relocation with CSX, which partially owns several of SEPTA's passenger railroads and provides freight service for national distribution, resulted in unfortunate yet avoidable flood consequences such as inundated rail vehicles, costly repairs, and weeks' long rail service decline (Gordon, 2011; Nussbaum, 2011).

3.3 Hurricane Sandy, 2012

At the end of October 2012, Hurricane Sandy provided the stage for another stress test of SEPTA's new storm policy and transport equipment. Sandy was the costliest hurricane event in damage loss (est. \$68B) next to Katrina (est. \$108B); and largest cyclone in diameter in U.S. history. Daily rainfall totals in several cities, including Washington, DC, Wilmington, DE, Atlantic City, NJ, and Philadelphia were broken (Greiser 2012). In Maryland, North Carolina, Tennessee, West Virginia, and Pennsylvania, heavy snows were dumped by the 'unusual' storm after mixing with an Arctic cold front. Voluntary and early transit system shutdowns took place in all affected areas, including the South,

Midwest, and Southeast regions of the U.S. However, the passenger risk and liability measure provided little benefit to exposed transport equipment located in all affected regions. Despite the article's focus on SEPTA and the Philadelphia metropolitan region transit agencies serving geographies in New York and New Jersey is worth noting for two important reasons. First, Sandy inflicted unprecedented system damage in New York City and its surrounding metropolitan region, which is inclusive of the southern parts of Connecticut and New Jersey, the most urbanized state in the U.S. Second, a high level of connectivity and commuter dependency exists between those systems and the ones in southeastern Pennsylvania. No other transit agencies received greater equipment damage than New York City's Metropolitan Transportation Authority (MTA), the Port Authority of New York and New Jersey (PANYNJ), and New Jersey Transit (NJTransit) as a result of Sandy's path of destruction. The cyclone's trajectory and impressive storm surge flooding caused extensive toll damage on transport infrastructure (e.g., subway tunnels, command and control centers, railroads, etc.) along the densely populated coastal shorelines of New Jersey and New York. Storm impacts generated an estimated \$7B loss for the most highly evolved and interwoven transit system network in the U.S., effectively disrupting the commutes of 40 per cent of its most loyal and needy users for days, weeks, and indefinitely in some communal cases (Hinds, 2012; Kaufman et al., 2012).

Sandy's directional track allowed SEPTA to avoid the painful burden of her sister agencies' recovery fates. In fact, as a display of its storm resilience and as a symbol of solidarity, the agency loaned a partial fleet of its buses to NJTransit to help support its

service schedule gaps (Redfern n.d.) However, completely escaping the storm unscathed was not in SEPTA's fortune. Equipment repairs and the removal of foliage debris along its regional corridors totaled an estimated \$550K (Jacobs, 2012). In the scheme of its grand transit system and business model, the financial sum was no small loss for SEPTA to endure. Full operational and business recovery from Sandy and other storms has yet to materialize since weather-induced damage and management costs continue each year with soaring levels of assurance suggests its managers.

4. Method

SEPTA's regional corporate offices and primary vehicle management control center are located in the City of Philadelphia in the neighborhood known as Center City. The agency shares high-rise building space with several of the municipality's administrative departments. Within SEPTA's service boundaries, bus depots, rail yards, heavy and light rail platforms, and trolley and bus stops are located in a wide variety of community types (Adams et al., 2007). Three transit service divisions support the agency's multi-modal network system, which sprawls across the jurisdictional boundaries of several municipalities. Firstly, the agency's City Transit Division handles surface (i.e., bus and trolley) and subterranean (i.e., subway) transportation routes in Philadelphia, with several bus and trolley routes extending beyond its political borders. Secondly, bus and light rail transportation routes in Philadelphia's close-in suburbs are overseen by the Suburban Transit Division. Lastly, the Railroad Division coordinates regional rail routes that served as impetus for SEPTA's original service and social contract with the many communities that exist throughout Southeastern Pennsylvania and parts of New Jersey and Delaware.

The case study on adaptive transit mobility for weather extremes in the Philadelphia metropolitan region was based on an analysis of semi-structured interviews with SEPTA's top- and mid-level managers (Table 1). The need to learn more about the managerial experience and outlook toward preserving and enhancing passenger mobility across a multi-modal urban transit system in extreme weather contexts drove method selection. Interviews make it possible for researchers to ascertain not only study subjects' dealings with the material and immaterial but also their viewpoints on how and whether they will advance their notions and actions for particular situations that may likely occur in the future (Dunn 2000). SEPTA's Office of Media Relations permitted the study and arranged interview schedules. The study received authorization for the use of human subjects from the Institutional Review Board at Rutgers, The State University of New Jersey.

Table 1 about here

Semi-structured interviews were conducted with managers at SEPTA between July 2011 and February 2012. An interviewer's guide was used to help capture managerial responses to open-ended questions centering on extreme weather vulnerability of the multi-modal network system; agency response policies, strategies and outcomes; the use of technology in organizing and ordering transport mobility during weather crises; ridership (re)actions to weather-related mobility adjustments. Interviews typically lasted for 1 to 1 ½ hour and were recorded with an electronic device and transcribed thereafter. Themes with a specific focus on adaptive mobility are highlighted for the purposes of this article.

5. SEPTA case analysis: adaptive mobility for weather extremes

5.1 *Extreme weather vulnerability: a range of impact factors*

Urban mobility calls for transport infrastructure and vehicle fleets that are functioning at maximum or even partial capacity. Interviewees spoke of how these important components of the Philadelphia metropolitan region's transit system were significantly influenced by a variety of impact factors while recalling extreme weather events that occurred in recent years. Meteorological factors tend to present the steepest challenges to managers, which some seemed to be uncertain with the agency's ability to keep pace with what appears to be a growing pattern of loss and recovery resulting from extreme weather events.

[Coping with weather extremes] is almost like a dance. It just feels like the dance is gettin' faster. We're dealing with 100 degree summers, and you get worn out from them. And you turn around and then you hope the fall's going to be okay and then you get hurricanes, and tropical storms and earthquakes. Then you assume well maybe we'll have a mild winter, and then we get hit like last year. We are fortunate that we had just as much snow as we could handle . . . anything more we would have been in trouble. And they did have more up in New York. And perhaps . . . I don't know how we would have done up there if it had been us. But because they did get more snow . . . It just appears that the weather is getting more and more severe and harder and harder to catch your breath between the events that come up. And like I said I think we are fortunate.

So what we try to do is get as much back on line as possible. But all these things have to be cleaned out. It takes manpower, all the switches, all the problems that we have . . . all the snow shoveling, the platform. It's a humungous task to try to keep up with all that. That's something that I didn't even touch on. The ice, the snow melt, the steps that lead down . . . we have people fall. All of these things contribute when we try to operate under those conditions it contributes to massive problems that . . . Frankly, in my personal opinion. We'd be better off saying we're not going to run this day either until we get it all cleaned up then we'll run. Because what happens is it gets mounting higher and higher. We fight it but it's not easy to come back on line.

Also, interviewees recognize that the temporal spacing of extreme meteorological events determines whether the agency can restore transit service and commuter mobility. Undoubtedly, restoring transit systems to their proper shape and operative functioning is

made difficult by tightly spaced events. Yet it is also understood that surprising and uninterrupted encounters with weather extremes also allow for the appraisal of the agency's weaknesses. Managers suggest that they use these compressed moments to evaluate system integrity and to further develop their ideas on how to make transit resilient to future occurrences for mobility sake. This implies that unless managers are forced to cope with events that impact the agency in the short-term the likelihood that they'll prepare for anticipated climate change trends in the long is less certain.

When you have a major blizzard, it's rare that you have multiple major blizzards. That one in 2010 was unique where there was three or four major ones. Historically, you get a major one and everybody reacts. Couple of days go by, you're back to some sense of normalcy. Just when you think that you're getting some equipment back, you get hit with another storm. And you lose more equipment. And you start getting back and then you get hit again. And you're never really able to recover from the effects of one big snow storm.

When we get hit event after event, we can seldom recover to our on-time performance. My perspective on that . . . like when it was last winter when we had those conditions. I wasn't even concerned about on-time performance. I was concerned about getting service through the line period. It didn't matter to me if it was thirty minutes, twenty minutes, ten minutes.

Sometimes successive events help because we gear up more. It's when we have that big gap when we went all those years with no weather problems. And I think that goes back to where we become more apt to recognize when it is more appropriate to suspend service because we've had these back to back events and we've gotten to see how we're affected. Because when you have that cycle of ten to fifteen years when you get only one or two major snowstorms in a season, and a major storm is 3 or 4 inches, 6 inches at most . . . That's no big deal in comparison to what we had for Christmas last year. As you get more practice at it you say oh, can we try this?

Another apparent factor in the vulnerability of SEPTA's transit system to weather extremes is the active presence of other passenger and freight companies in the Philadelphia metropolitan region. Managers expressed the idea that their inability to launch responsive and effective measures in some instances is due to the equipment and actions of others that are virtually beyond their control. Although there are far fewer operators in the region than there were thirty or more years ago, they appear to raise

difficulties for SEPTA management during weather crises as a result of joint ownership and use of material items such as railroads, signaling equipment, etc. In addition to detailing Hurricane Irene's cascading impact effects, managers at SEPTA spoke generally about the vagaries of disaster chance that accompany such arrangements.

And then there were other problems not only with what SEPTA maintains but AMTRAK had a major flood at Trenton. We had some cars that were submerged out there from our fleet, at least enough to do damage, the trucks and some of the electrical compartments. And then we also had an unbelievably flukish situation where, on CSX, a tree came down hit our feeder line, pulled our feeder down, our feeder came down then over the road crossing which was six spans away. Then our feeder came down onto PECO, then PECO came down. PECO came down on to the crossing apparatus, the device for warning protection for CSX, melted all of the equipment and sent energy back under the tracks through the cabling back into the signal house and burned it up overnight. So we had effects on both the system that SEPTA has and our riders were unfortunately impacted for quite awhile while Trenton dried out and while CSX had to rebuild a signal house and bring it up. They actually wired it somewhere down in the deep South and brought it up, trucked up, and put it in. So the inconvenience was substantial.

There are so many variables on the railroad side as opposed to the subway and the EL. They're more in a closed environment. We're so much subject to the extraneous things that can happen to us. And aside from that we're also subject to freight rail operations. AMTRAK's whims on how they operate. We're subject to their rules. Their trains are on three of our routes. We have issues with that.

Municipal (in)actions that lead to system vulnerability were also expressed as an area of frustration among interviewees. Transportation companies that preceded SEPTA and even the agency itself once took responsibility toward ensuring clear paths for vehicular travel. Today municipalities actively engage their resources to handle such matters so the agency is relieved of that burden in the technical and political sense of the word. The problem of transport mobility during weather crises lies in whether the transit agency and municipality can negotiate a route prioritization plan and effectively carry it out with the resources that they have at their disposal. However, not as readily apparent are the everyday municipal development activities that overlook weather hazards. Here it is worth noting that change occurs in environmental, management, and physical conditions so there needs to be ongoing discussions between SEPTA and municipalities within the

metropolitan region toward ensuring climate resilience for the systems that benefit the communities they jointly serve.

The [City of Philadelphia] can't keep up with us. They got their own problems. Every snowstorm you got neighborhoods that never got plowed. Can't get out. We had one snowstorm, we had the 15 down. And they say ride SEPTA. There has to be a better communication with that. We sit there now. We came up with a priority list for buses. We talked this out. The City has to plow these streets so we can get these buses running.

We're dealing with our vent wells in the subway. Besides covering them during Hurricane Irene what we're moving towards now is . . . In cities, what happens is they pave the streets and they keep coming up higher. They don't always mill and your curb goes away. Well, when the curb goes away and you get a heavy rain fall, we become a drain . . . for massive amounts of water into the subway. New York has had that problem as well. 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. So we're doing things.

Lastly, a less detectable yet powerful agent of transit vulnerability to weather extremes in the region are the mitigation practices of the transit agency itself. Here the importance of introducing climate considerations into infrastructure design and materials, planning, and investment is revealed. Managers spoke of how long-time remedies have conspired to produce unwanted and potentially disastrous results.

So we've had to deal with some very tough situations . . . When we introduced salt more on the Market-Frankford Line [as a result of snow and ice] we began to have situations where salt would find its way into new places and hit the third rail even though we moved it into the inside the tracks where the overpasses were . . . it was coming down on the overpasses and still causing a fire because it will short the third rail. And so we created reflectors right over the third rail in the overpasses so that the water wouldn't . . . I think you have to have a mentality from learning from your mistakes.

Individually and collectively, the vulnerability factors highlighted above present major obstacles to the effective functioning of SEPTA's transport infrastructure and vehicles. Interviewees speak of their effects as both tolerable and disastrous in times of weather

crises. Their responses imply a need for managers to be more proactive in incorporating climate change considerations into all aspects of the agency's managerial structures and operational procedures. Additionally, they point to the necessity of institutional partnerships that metropolitan regions need to have to address new climate regimes in a holistically rather than by piecemeal and individual effort. Such partnerships can be mutually beneficial to the climate resilience of transit systems and continued urban mobility across the region.

5.2 Extreme weather response: commuter adaptation?

Historically, SEPTA engaged each of its transit systems during extreme weather events until conditions forced a halt. The combination of small- and large-scale damage to equipment and disastrous situations involving passengers on vulnerable routes in recent years has since led managers to voluntarily interrupt service when operating conditions appeared or became less than optimal. Interviewees spoke of its new storm policy as a coup for the agency that has resulted in passenger safety, enhanced transit system resilience, and improved customer satisfaction.

And we're very proactive. We really don't want to have something happen. We rather catch it ahead ourselves, do the capital improvement, do the repair, whatever and not get in trouble. Not have riders be stranded, not have service be interrupted. And I think our customer service scores are a reflection that we can look at. Our on-time-performance numbers that we keep in our control center . . . I think our preparations for each year where we talk about what happened last year and make sure that we learned our lessons for the next year . . . Our people are so very non-interested in making the same mistakes twice.

However, the concerns that some managers expressed about commuters' lack of response to SEPTA's new operating procedures for storm events show a real pressing need for more attention to this area. Hurricane Katrina serves as a sobering reminder for municipalities and vulnerable commuters who are without alternative means of travel for short- and long-term transit disruptions resulting from weather extremes. Commuter adaptability to transit agencies' severe weather responses is an overlooked yet especially

salient issue that must be addressed in light of the fact that so few municipal emergency evacuation plans prioritize public transit as a viable safety option for their residents.

The main concern is always the passengers you're going to leave stranded. That's your main concern. How are we going to get the ones that are on the trolley or the train and how they're going to get home? Can we make it to the end of the line? And that's a question that's hard to answer because it depends on a lot of variables.

What you find is that ridership actually increases during bad weather because people don't want to drive their cars. When you increase the number of unfamiliar passengers that are out there and then suddenly . . . they don't understand why the system doesn't run on time like it's supposed to.

The biggest challenge is not the storm . . . We all know the weather forecasts are very . . . sometimes . . . unpredictable; all of a sudden at six o'clock in the morning we were basically already at 18 inches and it was coming down even faster; One of the factors that goes into our thinking is that if people hear that we're running they expect our vehicles to be on time. You know even though the conditions are impassable for regular motorists, if we're saying that we're running even with the delays people will come out and expect their bus, their train or their trolley to be there. If I cancel one railroad train and it's on a weekend which it was for the particular storm, I believe it was where you ended up. If you cancel one train that person's out there for almost two hours waiting for the next train and we don't know if that's necessarily going to go or not.

Interviewees express dissatisfaction with commuter behavior because the suggestion is that it compromises the implementation of SEPTA's operational procedures for weather extremes. Combining people's desire to relinquish responsibility for travel to the transit agency and transit dependency makes for a hazardous mix, even though the agency has and will take impressive measures to reduce its exposure and liability by eliminating its service indefinitely in times of weather crises.

5.3 Technological innovation: agency and commuter dependability

Opportunities to deal with the vulnerability of transit mobility to weather extremes are provided by new and innovative technologies. The technologies the transit world uses today are suggested to relieve managers of decision-making stress and provide commuters with comfort and safety benefits (Tang and Thakuria 2012; Watkins et al. 2011; Zhang, Shen, and Clifton 2008). Interviewees speak of today's technologies as blessings in helping to revolutionize the way in which SEPTA organizes and orders its vehicle fleet during normal and extreme operating conditions. However, it is suggested that managers continue to struggle with the human dimensions of weather risk management. A listing of transit technologies used in different management and operational contexts is provided in Table 2.

So we, through our systems, we can track our vehicles; All of our buses have GPS on them so we know where all of the buses are. We have . . . All of our subways, we have train-tracking where we can see where all of our subway cars are; we have tracking systems for our trolleys as well. We monitor the weather [using NOAA's website]. We make decisions based on . . . vehicles are being trapped or we're having some infrastructure problems.

I would say [internal agency communications] has improved tremendously. There are some kinks in it. We have what they call a command center. And when we have bad weather or any major incident they open up . . . all of the representatives from all of the departments are in the room. And they usually get more information, and by the time it gets funneled out they've already made up their minds. And that's when you got to have that time period to say think about what you just said. And then sometimes you can't.

Table 2 about here

Reducing commuter exposures to weather extremes with the aid of these technologies remain a bit of an open question. Commuter behavior is described by interviewees as a

disruptive agent to SEPTA's weather resilience efforts. This means that public education needs to be a major element of both agency and governmental efforts to help curb consumer vulnerability with respects to unawareness and unwillingness to adapt to new transit management regimes.

The media put it out. Again, I don't know where [transit commuters'] mind set is. But the majority of the people still believe you are going to run. And they're willing to get stuck.

Another apparent aspect of commuter vulnerability is the distribution of the transit agency's communicative capacities across urban space. Consequently, due to location disadvantage and route dependency some commuters lack fair and timely warning about transit service adjustments resulting from traffic congestion and road accidents, engineering failures, vehicular breakdowns, and weather surprises to name a few. Interviewees speak of such circumstances as unfortunate yet unavoidable. However, all passengers are equipped with the latest gadgetry to receive the agency's electronic service alerts while en route to their destinations is the assumption expressed by most.

[Bus riders] are [vulnerable] because of how many bus routes we have. We have a 100 . . . I can't even begin to tell you how many bus stops we have. So taking all of this into consideration . . . Yes, they are because how do you get the message out to them when we suspend service? So that the last bus or whomever it is . . . the poor operator that's coming down the street is just getting hammered with SEPTA sucks, blah, blah, blah, blah . . . and this thing and the other. And I'm not really sure of the answer to [the question of vulnerability reduction] because it would take masses amounts of money to try to put the LED signs at the different bus stops or at every bus stop which, as you know, everybody is under budget constraints. Nobody has any money, blah, blah, blah. I do know that we have Twitter but, as you say, your mother doesn't have Twitter but I'm sure your mother has a cell phone. If you have just a cell phone you can sign up for this site and it will give you alerts on your phone about SEPTA or different bus routes or whatever is. The only other thing I can possibly think of them doing would be . . . at your major bus stops. As far as them being the most vulnerable, they are because they don't have the conveniences of the iPhone or a more updated phone or even a computer. You know what I mean? So it does make [seniors] a lot more vulnerable. They just kind of go out, and stand, and wait for the bus.

Transit agencies and other responsible institutions cannot over- or under-state the importance of providing proper protections for transit commuters, particularly those least technologically, socially and economically equipped to cope with short- and long-term adjustments in travel service. The range of vulnerable impact factors make it nearly impossible to sustain what can be considered a travel safety net for growing numbers of dependent persons. Where managers instituted policy safeguards and technologies to cope better with extreme weather impacts, losses, and recovery, people's commuting circumstances and patterns served to compromise their effectiveness. To ensure the resilience and sustainability of urban mass transit in the face of more frequent and extreme weather activity calls for aggressive approaches transit agencies, municipalities, and the public need to be joined together in actions that help to engender fair and equitable decision-making centering on adaptive mobility. No one group or entity has the capacity or ability to do so.

7. Conclusion

SEPTA has taken steps to make adaptations to its transit system and management structure to better withstand impacts from weather extremes not out of anticipation but out of necessity. At the same time that the transit agency is undergoing adjustments in this regard, the municipalities that make up the service territory in which it operates are constantly changing economically, politically and socially. Their development or lack thereof adds another layer of stress to the agency's weather risk management schemes. Furthermore, the demands of an expanding base of transit commuters in the Philadelphia

metropolitan further complicate managerial and operational decision-making matters. The go it alone approach toward climate risk mitigation and adaptation the agency adopted prior to receiving government assistance to investigate its state-of-repair issues to reduce its vulnerability to extreme weather impacts demanded a closer look. The case study thus revealed a number of important items that the agency could no longer address in isolation despite its managerial and operational expertise and their best intentions.

This case study revealed a range of extreme weather vulnerability factors that weakened and disrupted transit mobility in the Philadelphia metropolitan region. These factors were shown to be meteorological, temporal, institutional, and governmental in nature. Despite moments where managers made it possible to cope with and deal with transit system setbacks in the short-term interview responses implied the need for SEPTA to incorporate climate considerations into every aspect of its management structure and operational schemes for long-term sustainability.

Commuters are an important yet often overlooked component of urban transit systems. Yet managers at SEPTA showed an appreciation for them notwithstanding their focus on cost-savings and liability reduction when speaking about the new storm policy the agency instituted in recent years to enhance their safety and security under stressful weather conditions. However, the study indicates that managerial assumptions about commuters' adaptive capacity indicate an obstacle to successful climate change adaptation not only across scales but also across population segments (Adger et al., 2005).

The modernization of transit systems should never be disputed because of the demands of a constantly evolving and changing world. However, when modernization disadvantages persons and their mobility it must surely be questions. Technologies that managers have incorporated into SEPTA's decision-making structure hold exceptional promise toward safeguarding commuter mobility before, during and after weather crises. However, human factors make them fall short of desired results. The case study reveals the need managers at SEPTA to take a closer look as to how and whether they evaluate commuters' use of technology for transit decision-making purposes, and those across their service territory that belong to vulnerable groups in particular.

In closing, the idea of joining transit agency, municipal government, and the public in equitable actions that foster shared responsibility for adapting public transit bears repeating. To do so, I wish to suggest the development of a public education program centering on weather extremes and public transit in major metropolitan centers and their close-in suburbs. Also, transit agencies and their municipalities need to invest in ongoing public campaigns that inform familiar and unfamiliar passengers about their extreme weather response protocols. Having policies that few know about and are surprised by them when they are implemented contributes to vulnerable risk.

Figures and tables

Figure 1

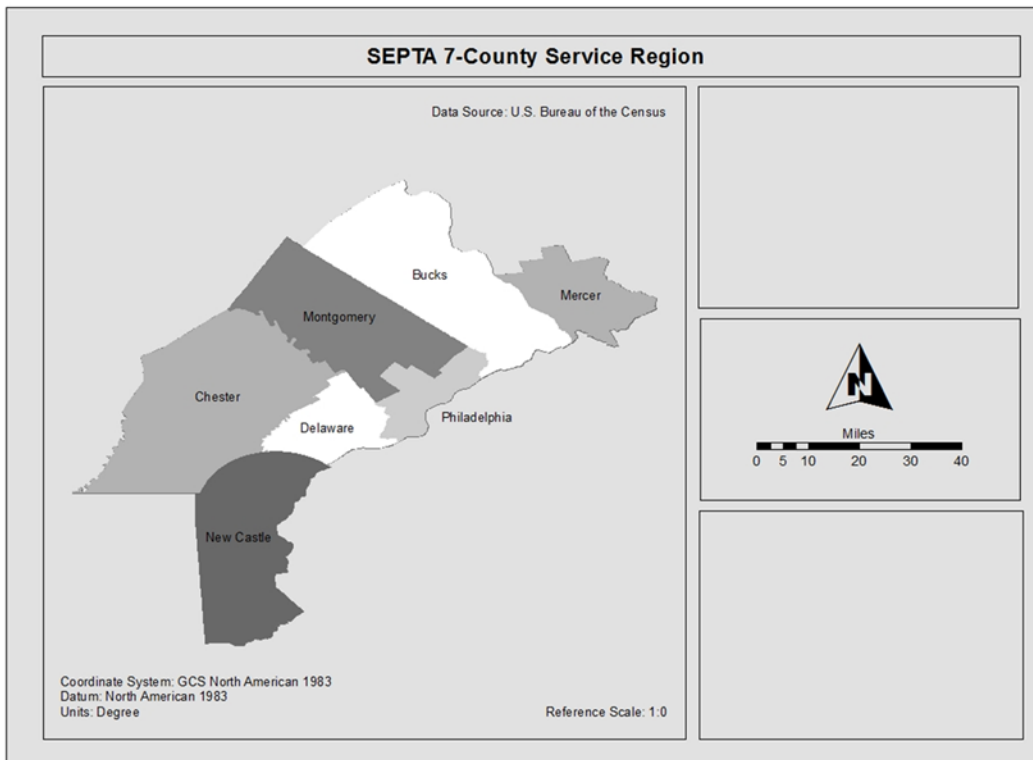


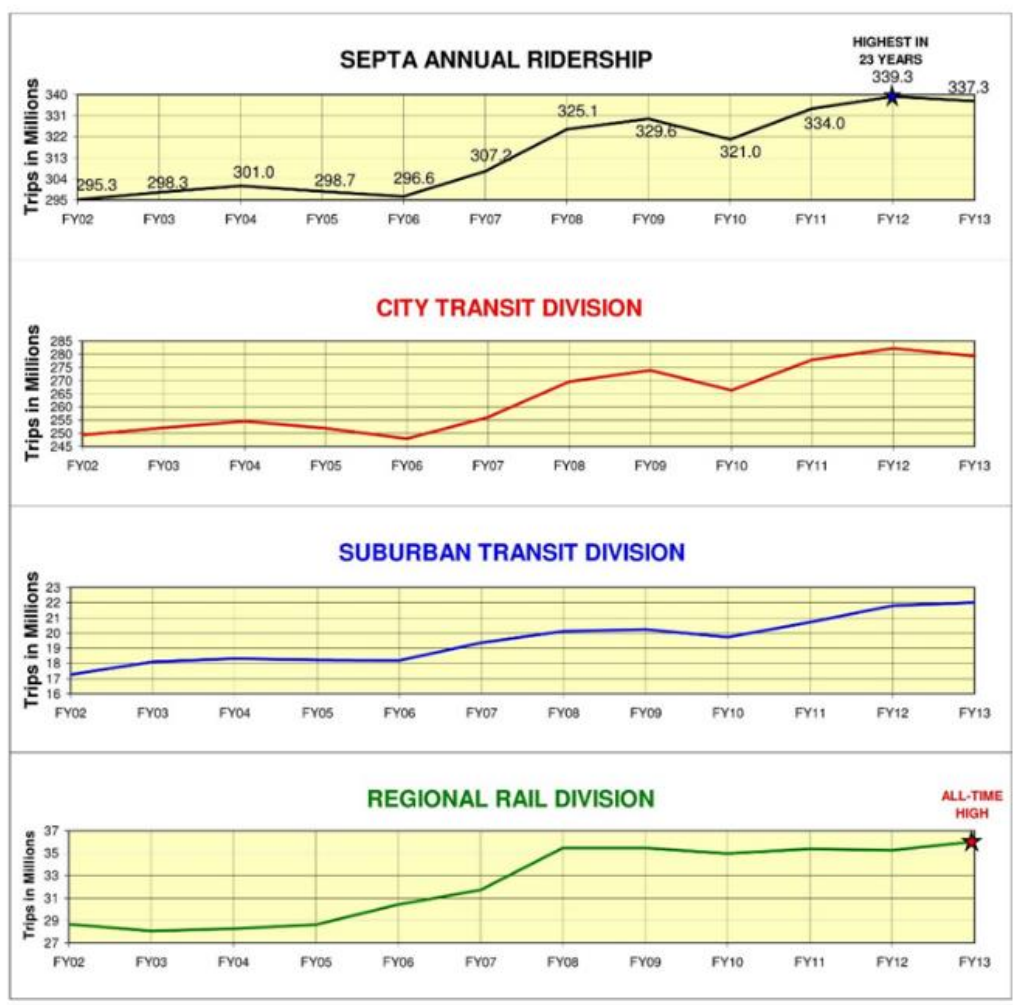
Figure 2

Demographic Profile of SEPTA Passengers				
	City	Suburban	Regional	Total
	Bus and Rail Transit	Bus and Rail Transit	Railroad	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

Figure 3



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.

Table 1

Respondents at SEPTA

Number	Respondent
1	Office of the General Manager Executive manager with administrative oversight over the assets and business and political affairs of the agency
5	Operations Control Center Executive and supporting managers with operative decision-making control over the agency's surface and subterranean transport vehicles and routes
1	Office of Engineering, Maintenance, and Construction Executive manager in charge of ensuring the physical integrity of transport equipment (e.g. railroads, bridges, etc.) and deals with work crew maintenance details
1	Office of Finance and Planning Supporting manager responsible for the agency's environmental sustainability program
1	Midvale Avenue Bus Depot Supporting manager in charge of bus dispatch scheduling

Table 2SEPTA Transit
Management
Technologies

End-user	Technology
Commuter	Mobile/Non-mobile technologies Twitter TrainView TransitView SMS Text Ready-to-Notify PA SEPTA's corporate website Radio Television
Management	Vehicle dispatch technologies Radio/Walkie Talkies GPS for vehicle tracking Phones Real-time train control and communications systems Asset monitoring CCTV Weather forecasting National Weather Service website

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