THE IMPACT OF CLIMATE CHANGE ON U.S. ROAD NETWORK AND CRITICAL INFRASTRUCTURE

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Introduction

Climate change is here. The effects of human activity over the years have exacerbated the long term effects on the global climate. Critical infrastructure across the United States is threatened by natural disasters that result in damaging outcomes. In 2020 alone, there have been record-breaking climate events: California has experienced raging wildfires that have burned millions of acres and displaced thousands of people from their homes, the Gulf and the East Coast are experiencing more severe and frequent hurricanes, and the weather is changing and becoming more damaging due to the rapidly progressing climate crisis. For the United States, this could result in heavy damage to the environment, loss of life, and a weakened critical infrastructure throughout the country.

Over the past few decades, the focus of national security in the United States has mainly concentrated on foreign and domestic threats, such as economic, border, and cyber security issues. After the World Trade Center attacks in 2001, the Department of Homeland Security prioritized combating domestic and foreign terrorism. However, the increasing frequency and severity of storms due to climate change pose a growing threat to those living in high-risk areas and critical infrastructures such as bridges, roads, and the power grid. These storms can leave permanent damage to large cities such as New York City or Los Angeles. Natural disasters such as hurricanes, tornadoes, and wildfires are beginning to pose an increasing hazard to American lives.

The transportation sector is an essential aspect of U.S. infrastructure. Significant damage to roadways inhibits transporting aid after a natural disaster to areas that need it most. Inaccessible roads can also prevent people from evacuating areas after a disaster hits. When

roads are closed or unusable for long periods, the damage caused by natural disasters can affect those who are outside of the direct impact zone. For example, in California, many wildfires can cut off roadways trapping people in one secluded area, unable to escape or have help come to them. The transportation system is accountable for quickly, safely, and securely moving goods and people throughout the country and overseas. Without accessible roads, communities are stranded from aid supplied by agencies such as the Federal Emergency Management Association.

Shifting the focus of local and federal agencies more towards climate change and its effects on U.S. critical infrastructure could prevent irreparable damage. I argue the United States needs to vigilantly protect its people against damaging natural disasters caused by the climate crisis by improving critical infrastructure security. The possible effects of climate change affect those in high-risk areas the most. These are areas that are susceptible to sea-level rise, wildfires, tornadoes, hurricanes, and earthquakes. If not handled earnestly, climate change could cause mass migration within the United States, extreme heat, and flooding, threatening the health of the public, infrastructure, and agriculture. The issue of climate change needs to be taken seriously to preserve the future of the United States.

First, I examine previous studies on the effects of climate change. These theories and scenarios demonstrate why climate change is a serious matter and should be considered a national security threat. I then investigate a case study carried out by the Federal Highway Administration examining the road network in New Jersey and mitigation and adaptation policies to improve and strengthen its road network. The case study results are recommended to be applied to other states' transportation departments and continue assessing roadways. I conclude

by arguing that because of the threats posed against human security, critical infrastructure security, and national and international security, climate change needs to be addressed and handled as an imminent threat to the United States.

For the United States and its people if climate change is not addressed in a similar way to other national security issues such as terrorism, there will be a serious threat for the country. For example, because of sea-level rise and wildfires, the chance of mass migration within the United States of those who live in these areas will increase as residents begin to move away from areas prone to damage from weather-related events. The Obama administration led the United States and other nations in the right direction to handle the climate crisis by introducing Obama's Climate Action Plan that presented a plan to cut the United States' carbon pollution. In conjunction with the administration's other actions and additional steps, the administration was committed to reaching the President's 2020 goal (Executive Office of the President 2013, 4-6). More recently, with the Trump administration, the United States has taken steps back by reversing policies and exiting the Paris Climate Accord. The attempt to lower the advancement of greenhouse gas emissions and reducing the global temperature has slowed down due to what the Trump Administration has planned. Handling the climate crisis is necessary, and it has reached a point where there needs to be a significant push to address it as a national security issue.

Literature Review

National security is broadly defined as the protection of a nation as a whole and its people (Holmes 2014). Under this definition, climate change should warrant the same attention as any

other national security issue. The threat to U.S. national security by our changing environment is imminent. The United States has been hit by natural disasters that have become more frequent and damaging with each passing year. Greenhouse gases, such as carbon dioxide released into the atmosphere by burning fossil fuels, are the number one cause of climate change. If the United States wants to reduce the effects of our warming planet, it needs to significantly cut its carbon emissions as part of a global effort to help lower greenhouse gases (Cunningham & Parillo 2013, 1).

For the United States, 2012 was one of the worst years of weather events compared to the past, with record-breaking storms and extreme climatic conditions. More than half the U.S. population was affected by some extreme weather. The Southwest experienced a record-breaking drought that had caused wildfires to burn 9.2 million acres in 2012, which was 50% higher than the 10-year average from 2001-2010 (Cunningham & Parillo 2013, 4). In October 2012, Superstorm Sandy made landfall near Atlantic City, New Jersey. When the storm reached New York City, it caused an estimated $70 billion in economic losses, tens of thousands of people were left homeless, and 7.5 billion people were left with no power for weeks after the storm had passed (Cunningham & Parillo 2013, 4-5). For the 2012 Presidential election, Hurricane Sandy affected it in more ways than one. Experts believed that the storm would impact the public's attitude towards President Barack Obama and his handling during and after the storm. Some felt that the storm would create negative attitudes towards the president. Others believed that Sandy would give Obama a chance to "look presidential" in his handling of the storm's aftermath days before the election (Hart 2014, 1). For the areas that were hit in the Northeast, the damage to roadways, transit systems, polling places unable to open, and displacement from their district

made it difficult for people to vote in the election (Velez & Martin 2014, 318). Suppose there are no mitigation and adaptation policies to protect the United States from extreme weather events. In that case, climate change will continue to be a threat to U.S. national security.

In the early 2000s, scientists across the country began to claim that there would be a shift in the earth's environment due to the effects of global warming. In 2003, scientific publications and political declarations articulated climate change as a threat to national, international, and human security. Oels (2012) presents three schools that offer theoretical perspectives on governing climate change as a security issue and offer different viewpoints on securitizing climate change. First, the Copenhagen Schools warns that a successful securitization of climate change could legitimize a political state of exception where dramatic mitigation policies are adopted using undemocratic procedures. The second school focuses on when climate change becomes a threat to human security. When this happens, sustainable development becomes a top priority on tackling pre-existing vulnerabilities and enhancing the adaptive capacity to the impacts of climate change. The Paris School perspective argues that the failed attempt of climate change securitization has resulted in the security field applying traditional national security policies to climate change. (Oels 2012, 185)

If not addressed forcefully as a national security issue, climate change will have damaging repercussions, leading to wars, mass migration, and terrorism. There will be major changes in damaging weather events that can drastically alter the planet's future within our lifetime. Homer-Dixon expressed that the stress from climate change could be compared to the arms race between the United States and the Soviet Union during the Cold War or the gain of nuclear weapons among rogue states (Homer-Dixon 2007).

Western governments have begun to see climate change as a serious threat to national security. Baysal (2017) argues that continuing to downplay the threats from climate change could undermine economic and political stability throughout the world and could become a threat multiplier, creating existing problems such as water scarcity and food insecurity more complex and difficult to control. When former President Obama received the Nobel Peace Prize, he warned the world that if nothing is done to combat climate change, "we will face more drought, more famine, more mass displacement – all of which will fuel more conflict for decades." (President Obama, Baysal 2017, 22). Along with other scientists and political leaders, the Ministry of Defense of the U.K. and the Pentagon have observed climate change as a threat to national security and have adopted mitigation policies into their operations (Baysal 2017, 22).

The United States, in the past, has been hit by storms where the damage is equal to a terrorist attack. Despite this fact, policymakers have been challenged with warranting climate change as a national security threat because there are no domestic or foreign agents behind the damage left behind. Busby (2008) argues the characteristics of an attack, such as 9/11, are more critical than whether outside agents were responsible: its suddenness, large scale loss of life, impairment of the country's critical infrastructure, and the need for military mobilization to prevent mass hysteria (Busby 2008, 488). Never before has humanity altered the planet and the environment in such a way that it created a national security threat. He believes there should be a focus on more short-run climate effects that allow policymakers and scholars to identify the potential security consequences and test them (Busby 2008, 471-472).

Discussing climate change adaptation costs for U.S. road network infrastructure following a natural disaster is essential for improving critical infrastructure security. The number

of cars on the road in the United States has been increasing each year and in 2019 reached 279.6 million operating vehicles (Statista). In 2017 alone, the trucking industry moved 10.8 billion tons of freight and moved more than 70% of all goods transported throughout the United States. If the transport halted for any reason, most grocery stores would run out of the product within three days. (John 2019). Particularly while storms are becoming more frequent and severe, and as the COVID-19 pandemic is resurging, the road network has become a top priority, and aside from being used for daily transportation, it is essential during a natural disaster for successful rescue, recovery, and renovation operations.

U.S. critical infrastructure is essential for responding to disasters. The highway system was created to allow for quick evacuation in the case of atomic attacks on large metropolitan areas in the United States. In 1956, President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956, which originated the Interstate Highway System, the largest and most expensive public works project ever initiated that created a 41,000-mile "National System of Interstate and Defense Highways" (History.com). Ike believed the project would eliminate unsafe roads, inefficient routes, traffic jams and would provide a fast and safe way to travel transcontinental (History.com). "In case of an atomic attack on our key cities, the road net must permit quick evacuation of target areas, mobilization of defense forces, and maintenance of every essential economic function. If we have a congested and unsafe and inadequate system, how then can we improve it so that ten years from now it will be fitted to the nation's requirements" (Eisenhower 1995, 2). While in 1955, the main concern for the Highway Interstate Program was created for nuclear disasters, it still applies today to have safe and adequate roadways when dealing with the effects of climate change. Over the years, the highway system

has developed into the extensive transportation sector that it is today and allows millions of motorists to travel and for cargo to be transported throughout the country. Because of its importance, adapting the roadway system to the ever-changing climate impact should be a number one priority for the United States.

Funds can be optimally allocated to repair urban road networks following a natural disaster. Karlaftis (2007) identified this method by testing data from the urban road network in Athens, Greece. The general framework covers inspection crews, emergency funding, repairs, and estimates of total funding and is applied to 400 bridges in the Athens area after two seismic scenarios. The study found that 15-35% of the bridges were damaged and that a proposed budget of 20 million euros would be needed to repair them (Karlaftis 2007, 86). The study's conclusion allocated the available funds to repair the bridges up to their lowest acceptable operational or pre-earthquake condition and estimated the necessary funds for repairing the entire bridge to its pre-event condition (Karlaftis 2007, 86). Applying this situation to the United States, transportation departments in each state could utilize Karlaftis' approach and implement it for bridges and other transportation sectors. Transportation departments would analyze bridges in high-risk areas such as California or the New York tri-state area. The process would allow budgets to be allocated appropriately to areas that need it most, and repair crews would be sent out to them. The scheduling of repairs could also be improved so that these areas are not closed for long periods. Throughout the United States, construction on roadways, bridges, and tunnels close these areas down, creating congestion in other areas. As Karlaftis did with Athens, planning out budget allocation and repairs will improve roadways over time and improve the process of budgeting and investigating critical areas during and after a natural disaster.

Chinowsky (2013) develops a methodology for estimating climate-related changes in road maintenance and construction costs to maintain the road network level of service over time. The paper assesses the costs for adapting the roads in the U.S. to changes in precipitation and temperature-related stresses associated with climate change by evaluating the cost of repairs (Chinowsky 2013, 766). The study allows for assessing adaptation costs geographically and assisting transportation planners in deducing the potential financial implications of climate change and its effects on the road network (Chinowsky 2013, 770). Chinowsky also made the methodology flexible and applied it to different climate scenarios than those presented in the study. They conclude there will be an estimated increase in costs of building and maintaining the U.S. road network, but some could also decline due to climate change mitigation policies (Chinowsky 2013, 771). Chinowsky presented two climate change scenarios to assess the adaptation costs for roads in the United States, the first being business as usual that assumes no federal regulation of greenhouse gas emissions and the second being a Global Action policy where aggressive policies are put in place to gain control and limit greenhouse gas emissions. Under the Global Action scenarios, the change in temperature that occurs after 2030 is significantly lower than the business as usual, and these results indicate that adaptation costs are lower under the Global Protection scenario.

With climate change rapidly advancing and creating more severe storms, U.S. critical infrastructure becomes more vulnerable. Similar to the finding of Chinowsky, Neuman (2014) explains that the progression of climate change and its effects on the U.S. road network can pose both risks and opportunities (101). Neuman uses four models that analyze vulnerability, impacts, and adaptation to roads, bridges, coastal properties, and urban drainage. Mitigation policy is

essential and provides a steady stream of avoided costs for the road network's four areas. With adaptation measures, such as using different pavement binders to avoid cracking, frequent re-grading of unpaved roads to limit erosion impacts, and frequent re-sealing to avoid rutting (Neuman 2014, 102), the United States would maintain the road network and allocate funds to improve roads, rather than waiting after a natural disaster to repair them. Mitigation policies are necessary when dealing with critical infrastructure and climate change and, in the long run, enhance the U.S. road network against extreme weather events caused by climate change.

Public transportation, another key component of the U.S. transportation infrastructure, is essential for urban sustainability. Effective transportation networks are vital for everyday needs, and if severely affected by an extreme weather event, it can leave the surrounding area incapacitated. Chang (2002) examined and evaluated enhancing public transportation performance in the aftermath of a disaster by using two case studies. The first is the 1995 earthquake in Japan, and the second focuses on the potential loss of road and highway transportation after a hypothetical earthquake in Seattle, Washington. Using these two scenarios, Chang can explain the importance of urban transportation and how it affects those in the community after a natural disaster. This is especially true in urban communities where the population is dense and urban transportation is a vital part of managing the city.

Understanding the impact that a weather event has on public transportation in a densely populated area can assist in adaptation policies for urban areas. In the first case, Chang examines the 1995 earthquake that struck the densely urbanized Hanshin region in Japan. The earthquake caused catastrophic losses with an estimated U.S. $100 billion in damages, which surpassed the 1995 Northridge Los Angeles earthquake, which was the costliest disaster in U.S. history. The

earthquake inflicted particularly severe damage to the port city of Kobe. The earthquake caused a massive loss of human life and property. In Kobe alone, 4,500 people were killed, and some 130,000 buildings were partially destroyed (Chang 2002, 1054).

Chang's analysis focuses on the loss of rail transportation, which is the primary mode of passenger transport in Kobe. The railway was severely damaged, and some parts took several weeks or months to repair, and disruption was particularly severe in the densely populated coastal corridor (Chang 2002, 1054). From this disaster, it is clear to see how essential and vital urban transportation is and how vulnerable it could be when faced with extreme weather events.

Using the Kobe earthquake results, Chang applies it to the hypothetical situation of an earthquake in Seattle. The scenarios presented a shallow magnitude 6.5 earthquake occurring in the Seattle Fault. Chang points out that an occurrence similar to this has a recurrence period of 500-1000 years and that the Seattle Fault has particular deadly potential as it traverses through densely populated urban areas (Chang 2002, 1064). The scenarios presented show that there would be potential bridge damage on interstate or state highways and that in the immediate aftermath of the earthquake, the most significant loss of accessibility would be experienced by communities on the east side that depended heavily on two bridges crossing the lake into downtown (Chang 2002, 1066). The surrounding area community would be unable to access aid or receive assistance from the downtown area until the bridges were repaired.

Chang concludes that urban transportation is vital for a densely populated area and that taking into account equity and accessibility in different areas of a city can be incorporated into decision making when planning for disasters that affect urban transportation. Transportation agencies can also apply the methodology presented in the study for disaster preparedness and

mitigation policies. The importance of pre and post-disaster preparedness and mitigation policies in urban transportation is necessary. New York City saw in 2012 after Hurricane Sandy hit and flooded the subway systems that it completely impaired an infrastructure necessary for those to receive assistance or be able to leave an area that is severely damaged. Changs results from the 1995 Kobe earthquake and the scenario in Seattle demonstrate that mitigation policies need to be put in place to prioritize sensitive and vital parts of the urban transportation sector.

New York City is the largest city in the United States, and climate change is one of the biggest threats to its infrastructure and those who reside there. Because of the city's diverse infrastructure, its complex transportation sector, and its proximity to the water, it serves as a guide on mitigation and adaptation policies for other cities in the United States to plan for future climate impacts. New York City is susceptible to sea-level rise, which poses threats to communications, energy, water, waste, and most notably, the transportation system. The city has the most extensive railway system in the country (Rosenzweig 2011, 106). There are seven local and regional transit systems in place, and three of them are managed by the Metropolitan Transportation System (MTA). Before the Covid-19 pandemic, it served 1.5 billion passengers annually within the city's five boroughs. Rosenzweig presents a table with the impacts of sea-level rise and its effects on the city's critical infrastructure by sector. Transportation will be affected by increased saltwater encroachment and damage to structures that cannot withstand the exposure. There has also been an increased rate of coastal erosion and permanent inundation of low areas resulting in increased maintenance costs and shorter replacement cycles. There would also be flooding of streets, tunnels, bridge entrances, subways, and structural damage in the case of sea-level rise and storm surges (Rosenzweig 2011, 107).

Because of the variation in height above sea-level, low-lying areas are common in the city's transportation sector and identified as vulnerable areas. For example, within the city's transit system, the highest point is the Smith and 9th Street station in Brooklyn, which is 91 feet above sea level, and the low point is about 180 feet below sea level in upper Manhattan (Rosenzweig 2011, 108). Due to the variety in the subway stations and the locations, there is a scale of vulnerability throughout the entire transit railway lines. An important factor to consider when applying adaptation and mitigation strategies is the configuration of a single railway line that is not interconnected with other lines, which results in little flexibility to shift to another rail line when another is disabled (Rosenzweig 2011,109).

New York City's challenges due to climate change are prevalent in other coastal cities globally. These cities are especially vulnerable to sea-level rise and face difficult challenges due to a concentrated amount of people and critical infrastructure in low-lying coastal zones, the inability to shift locales, the complexity of infrastructure, and the population's dependence on it (Rosenzweig 2011, 123). It is crucial for coastal cities, such as New York City, to start planning and putting policies to strengthen their transportation system and prepare it for drastic changes in the weather and its effects. Cities with densely populated areas must continually change policies to remain vigilant against climate change threats.

New York City's dense population brings up many challenges, such as pollution, overcrowding, and threats against the city's infrastructure and transit. In 2010, New York City had a population of over 8 million people, with approximately 14,000,000 residents in the surrounding metropolitan area (Solecki 2012, 557). Even before climate change, New York City was at risk of coastal flooding, storm surges, inland flooding of the street, heat waves, high wind,

and air pollutants—climate change only worsened these risks (Solecki 2012, 560). That said, there is a need to improve the city's resilience to environmental stressors. In 2006, former Mayor Michael Bloomberg created the Office of Long Term Planning and Sustainability to develop a comprehensive plan to create a greener and more sustainable city and strengthen climate change planning in the city. Bloomberg's focus on early climate change mitigation was to set an ambitious goal of a 30 percent reduction in greenhouse gas emissions from previous levels in 2005 by 2030 (Solecki 2012, 564). Because of these mitigation policies, New York City had become one of the leaders in climate change action. New York City began a dramatic re-visioning of the city's future, adapting to climate change to become more resilient to future weather extremes caused by climate change.

Post-disaster recovery is just as important as mitigation policies when dealing with the effects of climate change. Zhang (2017) developed a way to optimize the post-disaster recovery time for road-bridge transportation networks. The study incorporated network topology, redundancy, traffic flow, damage level, and resource availability (Zhang 2017, 1). Three aspects of the restoration process were addressed in the study. The first was introduced as two-dimensional metrics of total recovery time (TRT) and skew recovery time (SRT). This is a measure for network recovery planning, which is affected when resources are limited. Second, different prioritization can lead to significant changes in the TRT and SRT. Third, the scheduling frameworks and the algorithm applied can be used to obtain optimal solutions to handle large and complex networks (Zhang 2017, 9). Post-disaster recovery is an advancement in becoming resilient to natural disasters and climate change. Strengthening the post-disaster recovery time and functionality can allow areas that have been hit by storms to return to a sense of normalcy

after a weather event. Being functional and efficient in post-disaster scenarios is just as important as becoming resilient in pre-disaster situations.

The biggest concern with pushing climate change as a national security issue in the United States is that there is a divide between those who believe that climate change is posing threats to the United States and those who think it is a hoax. As Republicans begin moving to the right politically, the U.S. Environmental Protection Agency has increasingly come under attack from the right (Dunlap 2016, 6). Because of this, many supporters of the Republican party—and even moderate Democrats have a hard time supporting the claim that climate change is threatening national security, international interests, and human security globally. In June of 2017, President Donald Trump addressed the public, announcing that the United States would be pulling out from the Paris Climate Accord, which also ended the Green Climate Fund's implementation. According to Trump, he believed that the Paris Climate Accord was a disadvantage to the United States while benefiting others and that the Green Climate Fund cost the United States and vast fortune (White House Briefing 2017).

The Paris Climate Accord is made up of 196 nations from across the world and is an established document with multiple aims to tackle the issue of climate change. Some of the aims are to limit global temperature increase by reducing greenhouse gas emissions, provide a framework for transparency, accountability, and achievement, and to mobilize support for climate change mitigation and adaptation in developing nations (World Population Review). The purpose of the Paris Accord is to establish goals globally and for individual nations. When retreating from the Accord, President Trump claimed that with the United States in the Paris Accord, that the country would lose 2.7 million lost jobs, and the economy would be close to $3

trillion lost in GDP, and households would have $7,000 less income (White House 2017). A study done showed that if the United States officially pulls out of the Paris Accord, there could be detrimental effects to other responsive countries in the accord with a U.S. withdrawal. The study also found that even with a temporary U.S. withdrawal, it could cause emissions to become even higher and entail serious long term repercussions (Sælen 2020, 128-29). As a developed country and considered a superpower, the United States has a responsibility to uphold and plays a major part in handling the climate crisis as a national security threat.

Over his four years as president, Trump and his administration have dismantled more than 100 environmental rules in an attempt to promote industries like coal, oil, and gas. In doing this, these rollbacks have increased the level of greenhouse gas emissions, which will affect the quality of air, water, food, infrastructure, and other areas of the United States. Trying to push climate change as a national security threat in the past four years has been proven to be difficult due to rollbacks and not meeting set goals.

Case Study: New Jersey

Prior to Superstorm Sandy impacting New Jersey, the Federal Highway Administration (FHWA) began looking at mitigation policies that could be applied to strengthen New Jersey's critical infrastructure with a focus on the road network. The FHWA used a Risk Assessment to create a Conceptual Model used to aid different Departments of Transportation in dealing with the effects of climate change and how it impacts the road network throughout New Jersey. With a diverse road network throughout the state and having a coastline, the assessment was used to

diverse mitigation policies and ideas on how to strengthen different areas of critical fracture. The study was also available for other states outside of New Jersey.

The FHWA used the Conceptual Model with New Jersey as a case study and was used to provide feedback for heightening awareness and understanding climate change's potential effects in the transportation sector. The project was led by the North Jersey Transportation Planning Authority and supported by an interagency partnership, including New Jersey Department of Transportation, South Jersey Transportation Planning Organization, Delaware Valley Regional Planning Organization, New Jersey Transit, New Jersey Department of Environmental Protection, and New Jersey State Climatologist (NJTPA 2011, 10). The Conceptual Assessment was developed to help agencies identify infrastructures at risk for exposure to climate change stressors. Using the steps presented by the Conceptual Model, agencies can build an inventory of relevant assets and determine which are critical, gather information on potential future climate scenarios, and assess critical assets' potential vulnerabilities and resilience (NJTPA 2011, 10). The study focuses on two areas in New Jersey that are considered vital to the state's transportation sector. The first is the coastal area of the state from the Raritan River down to Cape May's tip. The second portion of the case study focuses on the Northeast Corridor, extending along the Delaware River from Trenton down to Salem County (NJTPA 2011, 10).

The case study is broken down into three steps. The Model first started with an Asset Inventory and Criticality Assessment, where information on roadways, passenger and freight railways, airports, and certain maritime assets were collected. They were categorized from "low" to "extreme" based on roles in connecting critical destinations and a combination of population and job density. Major railway lines and larger airports were considered critical. For example,

the coastal areas are at a high risk of damaging sea level rise and storm surges that could damage roadways, bridges, and railways that have high traffic and connect critical destinations (NJTPA 2011, 10).

The second step involves climate information. This step assessed the potential climate impacts for 2050 and 2100 from sea-level rise, storm surge, extreme temperature ranges, extreme precipitation levels, drought, and inland flooding. The Model found potential outcomes and was reported as low, medium, and high possible scenarios. The results showed that there would be a 5-meter increase in sea level globally, which would exacerbate storm surges due to hurricanes and nor'easters. Extreme hot temperatures would be more frequent, extreme rainfall events would occur more frequently, and increase inland flooding (NJTPA 2011, 11).

The third measure takes into account the Vulnerability/Risk Assessment. In this step, the Conceptual Model merges and superimposes the transportation sector and climate datasets to enable a spatial analysis of roadways, railways, and airports in New Jersey that are potentially vulnerable to the climate impacts mentioned in the second step (NJTPA 2011, 12). Implementing a vulnerability and risk assessment of the roadways every few years allows transportation departments to remain observant of any changes in the road sector and any new risk that may pose a threat.

In the 2100 scenarios, the Model found that mid-sea-level rise could impact almost 14 miles of roadways in the central study area, 1.4 miles of passenger transit lines, and 14 miles of major freight rail lines. For the coastal area of study, under the same sea-level rise scenario, this part of New Jersey could see over 48 miles of roadways damaged with 43 miles being considered primary roadways, 2.9 miles of N.J. transit inundated with about 31 miles of passenger and

freight railways impacted. For the coastal area, the Ocean City airport would be the only airport to be impacted (NJTPA 2011, 12).

The study's primary objective was to take the findings and present recommendations for the FHWA and the state of New Jersey. For the FHWA, the recommendations were to develop a policy response that would provide the planners and engineers with the thresholds that reflect the public consensus. This would allow an approach that would unite public risk tolerance with solid planning and engineering solutions (NJTPA 2011, 13). Another recommendation would be to use the process, and the data generated and collected from the study and apply it in a much broader sense to other critical infrastructure sectors (NJTPA 2011, 13). For the state of New Jersey, the study recommended that the state consider leveraging relevant data and findings from the study to perform a high-level vulnerability assessment for the entire state. The study's communication and collective learning should continue regularly and indefinitely (NJTPA 2011, 14).

Following the FHWA's recommendation, Rutgers University conducted its own study on how weather events impact the road sector a few years after Hurricane Sandy. Rutgers University and the New Jersey Climate Adaptation Alliance provided a summary of climate change impacts and preparedness opportunities for the many areas of the transportation sector in New Jersey. The report is a series of working briefs that provide background information on projected climate impacts for the six major sectors in New Jersey. The brief presents information and develops recommendations for the state and local public policy to enhance climate change preparedness and resiliency in New Jersey (Rutgers 2014, 1). While the Rutgers study also found that climate change is likely to affect transportation, it will also affect certain disadvantaged groups such as lower-income, elderly, disabled persons, and those dependent on public transit to

travel between home, work, or social services (6). The vulnerability of the urban transportation sector also poses a significant risk to the population of these communities. Rutgers' recommendations are similar to the one presented in the study conducted by the FHWA. Understanding the infrastructure vulnerabilities can help develop more targeted investments in infrastructure to create a more resilient transportation system in New Jersey (Rutgers 2014, 10).

The findings from the FHWA and Rutgers Climate Change Alliance reports demonstrate that mitigation and adaptation policies are necessary if New Jersey and other states want to prepare their roadway sector for future climate impacts. After Sandy's impact, much of the FHWA recommendations still stand; the only change would be to constantly update any mitigation and adaptation policies that were put into place. Suppose New Jersey wants to remain vigilant in handling the impacts of climate change against its road network and other critical infrastructure. In that case, the state needs to be assessing vulnerabilities in the roads and revamping mitigation policies yearly. The devastating results from Sandy show how important it is to stay ahead of damaging weather events. While it is expensive for states to be overprepared earlier rather than waiting for the last minute, adopting adaptation policies is needed to protect the critical infrastructure in the state and provide safe roadways for people to use during a natural disaster.

Discussion

In 2009, the state of New Jersey began processing adaptation and mitigation policies in preparation for severe weather events. The purpose of this was to assess vulnerabilities throughout the state and to combine constituencies statewide so that New Jersey could be

proactive in the adaptive capacity in preparation for climate change (New Jersey Department of Environmental Protection 2009, 88). Hurricane Sandy was the most destructive hurricane to hit during the 2012 season and demonstrated the importance of mitigation and adaptation policies to strengthen the road network and other critical infrastructure sectors. There were many takeaways from Sandy that states along the east coast, more specifically New Jersey and New York, are considering when implementing policies based on climate change. For New York City, a top priority was the transportation sector due to the subway line being shut down due to flooding and damage. New York City took into consideration what happened after Sandy and began looking more closely at sea-level rise, storm surges, and the proximity to the water when implementing new policies and changes to the city. For New Jersey, rebuilding the coastline and strengthening the beaches was a critical aspect of the post-Sandy recovery. New Jersey also strengthened its power grid so that future storms wouldn't shut down the power to water treatment plants and centers, allowing the state to have access to clean water.

Before Sandy, states across the United States began implementing local climate change initiatives. In 2005, the U.S. Conference of Mayors adopted the Mayors Climate Protection Agreement, which urged mayors across the United States to adopt mitigation measures to meet or exceed the timetable for reducing greenhouse gases. By November of 2007, mayors from 710 cities across the United States joined the agreement to combat climate change. They began by strengthening their cities' critical infrastructure, lower their greenhouse gas emissions, implement energy-efficient designs, invest in mass transit systems, and switch over to waste management programs that use less energy. New Jersey, being one of the states to join the agreement, was led by Robert Shinn, the Commissioner of the New Jersey Department of

Environmental Protection, and receives much of the credit for his state's early leadership on climate change (Engel & Orbach 2008, 122-133).

Having government leaders support studies done on their state will allow for better implementation of mitigation and adaptation policies. In 2011, the Federal Highway Administration created a Conceptual Model to continue the risk assessment throughout New Jersey. The FHWA also provided scenarios necessary to create mitigation policies to prevent possible damage from possible weather events. Understanding the road sector's vulnerabilities in New Jersey and its risks to extreme weather events, having reports conducted similar to the FHWA's is vital to remain vigilant in protecting and strengthening New Jersey's critical infrastructure. The importance of reports like the FHWA's report is that other states can review them, assess their own state's infrastructure vulnerabilities, and mitigate funds, policies, repair crews, and any plans.

Solving climate change and combating the threat it poses to U.S. critical infrastructure should be a top priority for officials at the state and federal level. While states have begun adopting new policies to lower their emissions, there needs to be a push for more drastic measures to be taken. The FHWA recommended that risk assessment and the communication of vulnerabilities be conducted indefinitely if New Jersey and others want to continue improving their infrastructure. Securitizing climate change will allow government officials at all levels to handle the situation as any other national security issue. However, dealing with the public's polarization and even government officials makes it challenging to flip climate change as a threat to national security.

Conclusion

The 2011 FHWA study demonstrated what the future of critical infrastructure in New Jersey could look like. Adapting the road network to ensure that when an extreme weather event hits, the state is prepared to handle the outcome of whatever happens. Being able to effectively mitigate the effects of climate change on various sectors of the critical infrastructure throughout a state can improve the state of the sectors before, during, and after a storm. The following year when Hurricane Sandy hit New Jersey and New York, the damage caused to the state's infrastructure was the worst ever seen. In the state of New Jersey alone, hundreds and thousands of homes were destroyed, drinking water systems were affected by power loss, water treatment plants were affected by power loss, and the entire coastline of beaches experienced significant erosion (New Jersey Department of Environmental Protection 2015, 1). After Sandy, the federal government stepped in to provide aid in the areas that were severely damaged. They assisted in rebuilding areas, providing access to shelter, food, clean water, and providing states with emergency funding to get back to pre-Sandy conditions. However, after the federal government leaves when recovery is partially complete, states are left to deal with the remaining damage independently. This is why states need to push local mitigation and adaptation policies and assess their own critical infrastructure threats to prepare for storms similar to or stronger than Sandy.

One way to overcome partisan opposition to climate change mitigation efforts would be to articulate the issue as a threat to U.S. national security. If climate change were to be spun like a top priority for national security, the probability of an infrastructure bill that would increase spending and funding, implement drastic measures and policies, and direct funds to cities in

high-risk areas. Having a big infrastructure bill could be what is needed to push the public and political leaders into the direction of flipping the narrative and addressing climate change as a national security issue. Still, the push back from some political leaders makes it difficult to pass big infrastructure bills that would begin strengthening roads and transit and other critical infrastructure sectors.

One way to encourage the passage of such a bill would be to assure benefits are distributed across as many congressional districts as possible. A similar dispersion of benefits prevented many military bases throughout the United States from being closed in the 1990s (Wildavsky and Caiden 2003, 177). Likewise, defense contractors gained congressional support by distributing the B-1 bomber production throughout 48 states and 400 congressional districts, which allowed for the cultivation of political support by creating large programs and dispersed constituencies (Wildavsky & Caiden 2003, 177). If the United States were to propose a large infrastructure bill and make sure that it is passed and implemented, using the same approach taken by the defense sector and spreading out infrastructure spending across many states could facilitate such a large bill.

The threat of climate change is obvious. Severe storms that could bring permanent damage to critical infrastructure are imminent. For future scholars, analyzing different scenarios to understand how to improve critical infrastructure should become a top priority when climate change is brought up. Studying how roads and other critical infrastructure sectors are affected by climate change and the long term effects could help scholars and governments mitigate and adapt to climate change and improve critical infrastructure throughout the United States. From the public standpoint, pushing government officials to flip climate change as a national security issue

could lead to a drastic change that the United States needs, especially after four years of pulling out of important environmental policies. The public's pressure on their local and state governments could also push the federal government to strengthen critical infrastructure further rather than repair it to its pre-storm capacity. Taking these steps to adapt, mitigate, and invest in the U.S. critical infrastructure sectors starts from combating climate change aggressively and flipping it as a national security threat.

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