Credit Ratings & Climate Change Resilience:
A Framework for Assessing Airports, Seaports, & Toll Roads

Submitted to Fitch Ratings Global Infrastructure and Project Finance Group

Practicum in Transportation Policy, Operations, and Logistics

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Foreword

The Master of Arts in Transportation Policy, Operations, and Logistics (TPOL) program at George Mason University is designed for students and practicing professionals engaged in planning, regulating, managing, and operating transportation facilities and services. Students obtain a working knowledge of the theory, policy, law, research, and practices required to supply and operate transportation facilities and services effectively and efficiently. They also learn to think critically and analytically about the problems and challenges in this field and communicate their analyses clearly and effectively through written and oral presentations. The TPOL program culminates in a capstone project where students collaborate with faculty and industry to address a relevant transportation issue. This report is an example of such an effort.

This report may be of interest to the transportation research community and planners. Its intended purpose is to provide Fitch Ratings with a different perspective and approach to incorporating climate change resilience into their transportation credit rating analysis.

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Disclaimer
The opinions expressed or implied are those of the graduate students that performed the research for this report and not those of Fitch Ratings, George Mason University, or of any government agencies or organizations mentioned in this report.

Executive Summary

This report provides a framework for incorporating climate change resilience in Fitch Ratings' credit rating assessments of airports, seaports, and toll roads. We build on current transportation resilience practices and climate-related assessments, key credit rating drivers, stakeholder interviews, and analysis of nonrecourse municipal securities official statements to develop a conceptual resilience framework that may be useful in expanding into Fitch Ratings credit rating process for transportation projects. This proposed framework can help develop quantifiable information to determine a project's resiliency by analyzing these factors: project type, asset-level; asset productivity; and strategic response planning. By focusing on the vulnerabilities and portfolio exposure, the framework provides a means to assess a project's climate-related risks and resilience that can be easily distinguished between a high, medium, and low risk-resilience metric.

Key Findings and Recommendations

1. **Measuring Transportation Resilience**
    a. **Finding:** There is not a widely accepted practice for measuring resilience of transportation infrastructure to mitigate risks and inform investment strategies.
    b. **Recommendation:** Develop a quantifiable project climate-related risk-resilience metric and incorporate for use as a credit rating driver based on the proposed framework of this research.

2. **Climate Change Resilience Disclosures in Official Statements**
    a. **Finding:** Over the last ten years, attention to climate change resilience in official statements has improved significantly but requires more comprehensive information on the impacts of climate change on transportation assets.
    b. **Recommendation:** Engage stakeholders to improve how climate change resilience is addressed in a more clear, comprehensive, and quantifiable approach in official statements.

3. **Expected Benefits of Resilience Investments**
    a. **Finding:** Typically, transportation projects that have invested in resilience do so for the next five-years with a focus on immediate natural disasters and the most likely security threats due to limited resources and competing priorities.
    b. **Recommendation:** Consider a benefit-cost analysis that can help determine the appropriate level of long-term climate change resilience investments, both in periods of normalcy and disruption.

Introduction/Problem Statement

This report identifies ways to develop a framework for assessing the resilience of airports, seaports, and toll roads to changes in climate, including asset condition, productivity, and demand. Its purpose is to provide Fitch Ratings – a nationally recognized statistical rating organizations (NRSRO) designated by the U.S. Securities and Exchange Commission – with findings and recommendations that can inform its approach to incorporating resilience into its transportation sector. Fitch Ratings assigns credit ratings to issuers or obligations including those where repayment is dependent upon cash flows from the ownership or operation of infrastructure or project finance transportation entities. This report is focused on such self-supporting assets, specifically airports, seaports, and toll roads operating in the United States of America. While climate change can impact most transportation assets, this project does not assess the resilience of non-self-supporting transportation assets including non-tolled roads/bridges and public transportation.

According to the federal government, from section 12 CFR 1.2 – Legal Definitions, investment-grade is defined as "the issuer of a security has an adequate capacity to meet financial commitments under the security for the project life of the asset exposure. An issuer has adequate capacity to meet financial commitments if the risk of default by the obligor is low and the full timely repayment of principal and interest is expected." An associated credit rating is expected with a purchase or sale of any bill, bonds, or notes. Potential climate change impact to the asset's condition, productivity, and demand has therefore been either minimally studied or left out completely. This project aims to provide a framework for investors to consult and assess risk for climate related issues for transportation assets.

Recently the Securities and Exchange Commission (SEC) announced it will discuss plans for proposals for climate risk disclosures (Walters & Manson, n.d.). The justification for investors wanting this information is two-fold. First, investors want to know the risks associated with investment choices so they may avoid those that could be too costly for their portfolios (Walters & Manson, n.d.). Second, investors are interested in knowing the commitment to environmental, social, and governance (ESG) of the companies in which they choose to invest. The SEC also has the challenge of ensuring the company's sustainability is based on reality. (Walters & Manson, n.d.). The proposed plan regulating climate risk disclosures would make US policies consistent with other countries around the world. (*For Climate Policies to Stay on Track We Must Prepare for Transition Risks*, n.d.)

Research Approach (Methodology)

A four-phase approach was used to develop a potential transportation climate resilience framework. The first phase was conducting research published transportation literature and existing resilience and vulnerability assessments due to climate change. The second phase was conducting stakeholder interviews with federal and state departments of transportation, transportation research organizations, and financial institutions. In the third phase, a sample of official bond issuance statements for non-recourse municipal securities for airports, seaports, and toll roads were reviewed to explore what information they contain about resilience to changes in climate. In the fourth and final phase, the information gained from phases one through three of the research was used to create a potential transportation climate resilience framework for investors. The research approach is summarized in Figure 1 below.

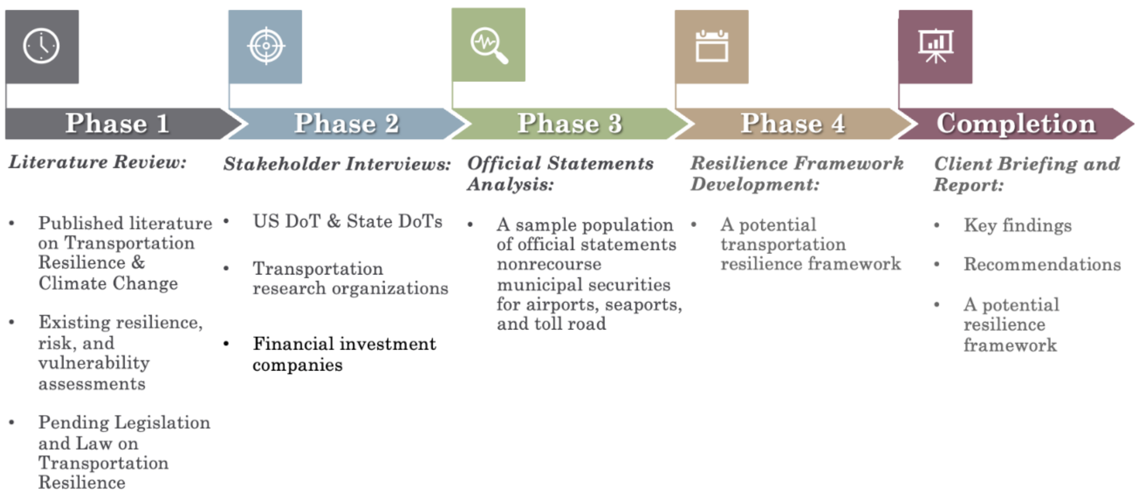

Figure 1. Summary of research approach for climate resilience

Understanding Climate Change and Asset Resilience

Climate Change

Climate change is the rapidly changing weather patterns that have been observed since industrialization began, due to increased greenhouse gas emissions in the atmosphere. Climate change contributes to natural hazards by altering historic patterns of weather events. NASA defines climate change as the "long-term change in average weather patterns that come to define Earth's local, regional, and global climate." (NASA, 2022) Varying temperature includes abnormal increases in very hot days or very cold days deviating from historical weather and climate patterns (TRB, 2008). Extreme weather events from climate change are the main threats to transportation infrastructure.

Climate change continues to grow in importance in transportation, finance, and other sectors/industries. Globally, climate changes affect everything, including transportation assets, existing and new projects alike. Bridges, roads, and ports, for example, are designed to last for decades; however, not all designs take future climate change effects into account (NOAA, 2021). This report examines the climate impacts with increase in occurrence and intensity of hurricanes, extreme temperature, precipitation, sea level rise, and changes in local wind patterns.

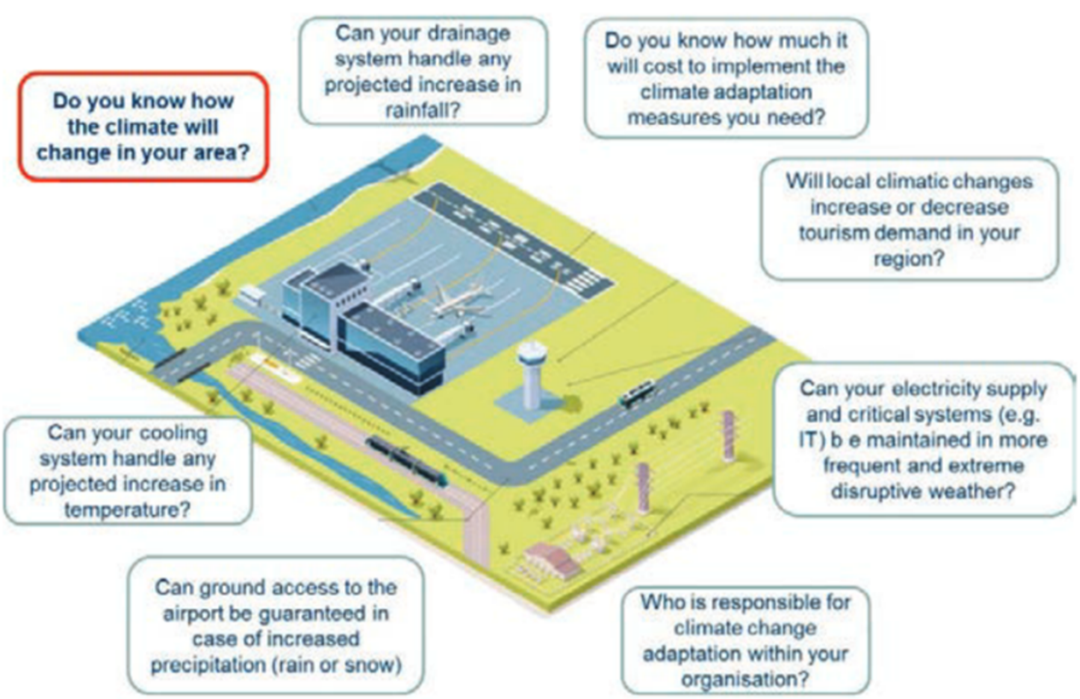

Figure 2. Climate change risk assessment: initial questions to ask

Image source: Science Direct

Average global temperatures are expected to increase by as much as 2.7˚F by 2050 and 3.6-7.4˚F by 2100, with most of the United States land expected to increase in average annual temperature. The National Oceanic and Atmospheric Administration predicts that US coastal cities will see up to one foot of sea level rise by 2050. Nearly 40 percent of the US population lives in coastal counties. Infrastructure developed in these areas will be affected by sea level rise. Facilities built in coastal and other environments that will experience extreme weather conditions are more at risk and must prepare for future climate change events to remain resilient. An example diagram of airport climate resilience – questions to ask is summarized above in Figure 2. (NOAA, 2021)

Risk Factors and Vulnerability

Vulnerability is defined as the quality or state of being exposed to the possibility of harm or damage. Transportation facilities are continuously exposed to their surrounding climate which increases the likelihood they may fail when exposed to extreme events and no longer be available to meet demand. When determining vulnerability, one must consider the geographic proximity to the source or origin of the event causing damage or harm, as well as the probability of occurrence and the consequence should the occurrence come to fruition. (Chen et al., 2015) The severity of climate change impacts depends on the vulnerability of the asset to the type of weather event. An example for airports and vulnerability to climate change is shown below in Figure 3.

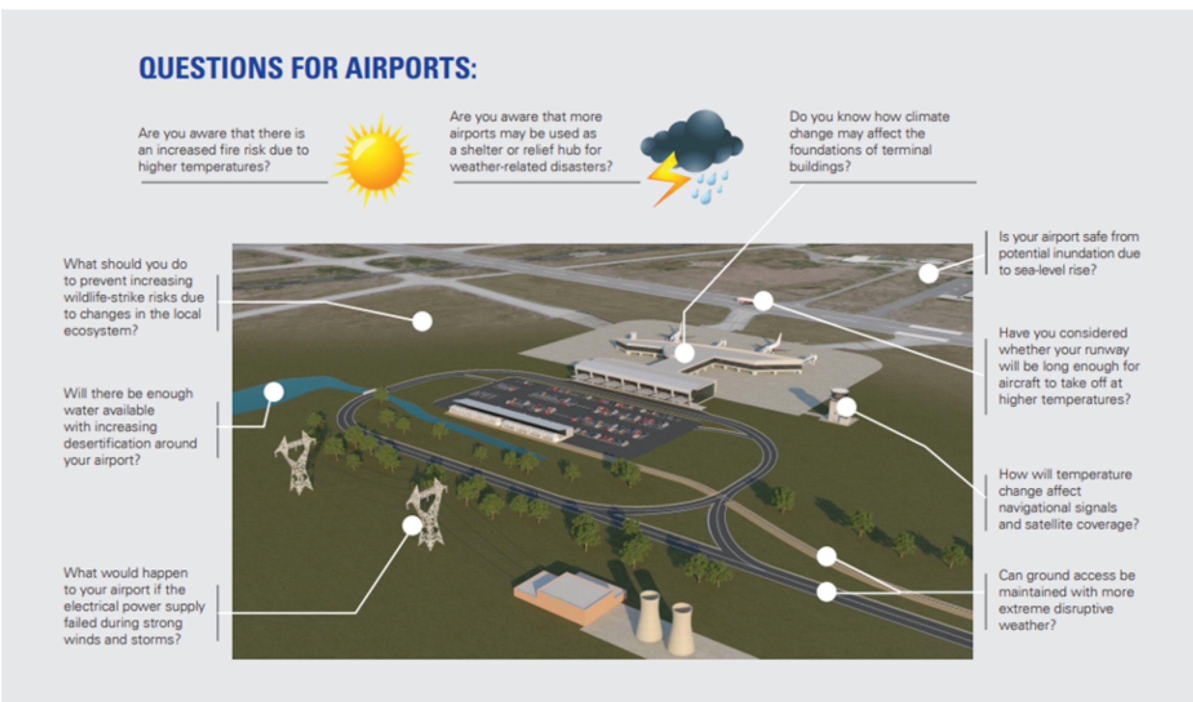

Figure 3. Climate change risk to airport facilities: initial questions to ask

Image source: Airports International Council

Extreme weather events, such as greater temperature variations, increasing intense precipitation events (including hurricanes), and sea-level rise would have significant impacts on the design, construction, maintenance, and operation of transportation infrastructure if they are to remain serviceable and profitable. Impacts from these extreme weather events could exceed historical design parameters used in transportation infrastructure. As these impacts exceed design parameters, the probability of impacting the productivity provided by transportation infrastructures increases (TRB, 2008).

Using risk matrices helps establish design parameters that can reduce vulnerability. For instance, using a risk exposure matrix like the one shown in Figure 4, higher design standards would be prudent to reduce vulnerability if the probability of an extreme weather event is high and the severity or damage caused by the event is high (cell 5A). Alternatively, a low probability, minimally damaging event, would not justify the additional cost of higher design standards (cell 1E) to mitigate the impact of the event occurring. This approach can help reduce vulnerability and make the best use of constrained resources when designing and constructing transportation infrastructure.

SAFETY RISK		Severity				
Probability		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

Figure 4. Risk exposure matrix: severity vs. probability

Image source: ICAO Climate Resilient Airports

Impacts on infrastructure can expand over time. Within the lifespan of infrastructures, adverse impacts from climate change can cause premature deterioration of infrastructure, shorten their lifespan, cause safety concerns, reduce productivity, and increase costs on design, construction, operation, repair, and maintenance. (TRB, 2008) This decreases the infrastructure's productivity and capacity to meet demand. Impacts vary by mode of transpiration and region of the country. These would have collateral costs on society and the economy. An example of projected climate impacts and changes in demand to airport infrastructure is shown below in Figure 5.

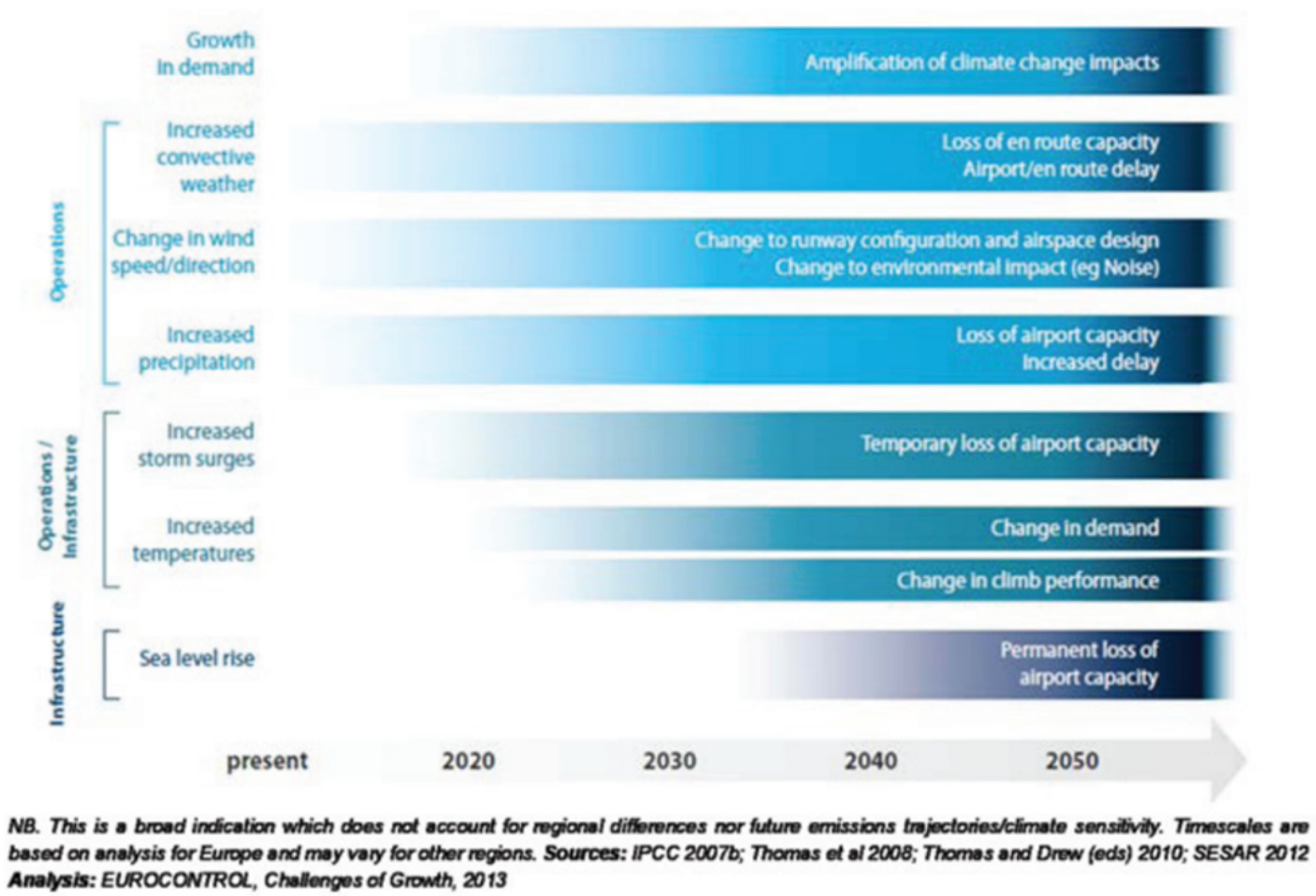

Figure 5. Projected impacts to infrastructure and operations of airport facilities due to climate change

Image source: Science Direct

Risk

Taking climate into consideration in deciding whether to invest in an asset is increasing in importance. Risks will continue to impact infrastructure as the course of climate change continues to expand. Furthermore regulators, customers and shareholders are demanding immediate review and action. (Finley & Schuchard, n.d.).

When evaluating climate change on toll roads, airports and seaports, the focus of the fundamental types of risk are on infrastructural risk and operational risk. Infrastructural risk is an indicator that quantifies the deviation from the objectives of reliability and functionality of the infrastructure, derived from the occurrence of failure modes. Operational risk is an indicator that quantifies the deviation of the economic objectives or quality of service provision of an activity, derived from the occurrence of failure and/or stoppage modes in an area of operational interest. (Gómez & Molina et al., 2018).

Figure 6 shows the risk, or level of uncertainty, of different types of climate change occurring, which can in turn help assess climate change risk to transportation systems.

Potential Climate Changes of Relevance to U.S. Transportation	Level of Uncertainty
Temperature	
Increases in very hot days and heat waves	Very likely
Decreases in very cold days	Virtually certain
Increases in Arctic temperatures	Virtually certain
Later onset of seasonal freeze and earlier onset of seasonal thaw	Virtually certain
Sea level rise	Virtually certain
Precipitation	
Increases in intense precipitation events	Very likely
Increases in drought conditions for some regions	Likely
Changes in seasonal precipitation and flooding patterns	Likely
Storms	
Increases in hurricane intensity	Likely
Increased intensity of cold-season storms, with increases in winds and in waves and storm surges	Likely

Figure 6. Likelihood of climate change events

Image source: [TRB Special Report 290]

Asset Resilience

Resilience is "the ability to resist, absorb, and recover from or successfully adapt to adversity or a change in conditions, while still retaining the same controls on function and structures." (Wolfe, 2021). Transportation assets are vulnerable to events such as: extreme temperatures, wildfires, intense precipitation, hurricanes, flooding, sea-level rise, and changing wind patterns. In the United States, the transportation sector alone is responsible for 29% of all greenhouse gas emissions, contributing to its own demise against climate change resilience. (EPA, 2020) Toll roads, airports, and seaports are no exception. It is important for transportation infrastructure asset managers to prepare for the future and consider resilience of their infrastructure against climate change.

Shock events, such as major climate change events, can impact transportation infrastructure. The resiliency of the infrastructure to climate change shocks determines how well it recovers from the event. Figure 7 illustrates the recovery timeline for more sustainable and less sustainable systems, reinforcing the importance of resiliency in transportation infrastructure to minimize impacts.

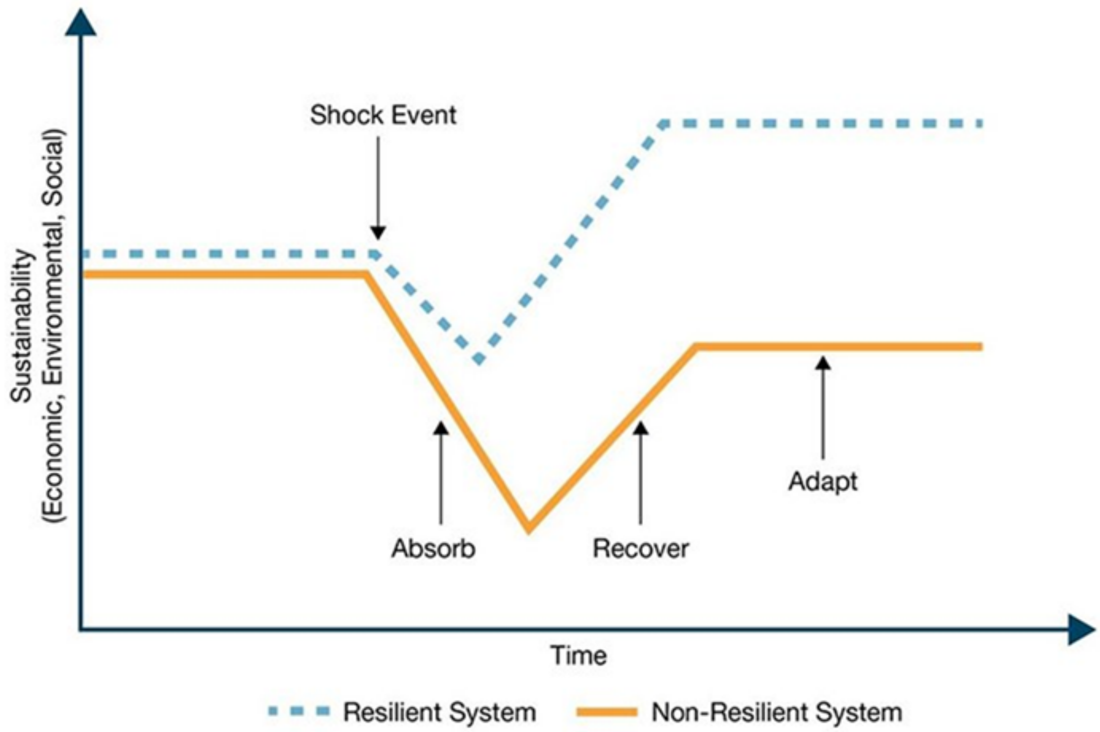

Figure 7. Impact on sustainability and resiliency after a shock event

Image source: ESA – Defining Airport Resilience

One must also overlay the typical climate environment in the various parts of the country. The following graphic and associated table depicts ten different US climate regions as outlined in the Fourth National Climate Assessment (USGCRP, 2018). Appendix D contains a summary of the different climate conditions, weather events, and future climate projections found in each region outlined in Figure 8 below.

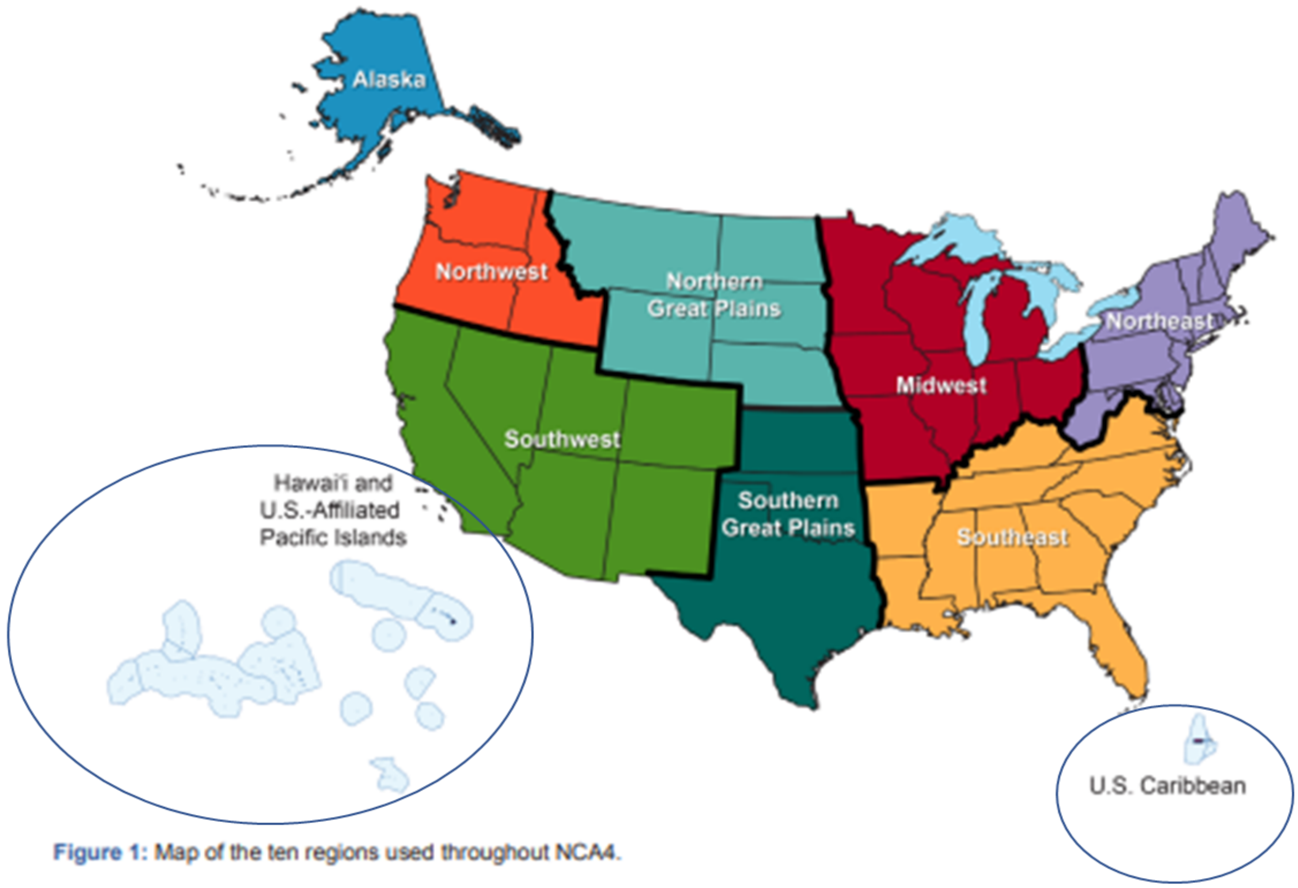

Figure 8. Map of the ten climate regions in the United States

Image source: Fourth National Climate Assessment

In determining the creditworthiness of these assets, it is proposed to investigate the asset using the lens of climate change in the context of the climate environment for which the asset resides. The three categories of focus include asset conditions, productivity, and demand.

Asset Conditions

Extreme weather events – temperature changes, sea level rise, increased storm intensity (hurricanes, increased precipitation) and frequency, extreme temperature/wildfires, and changes in local wind patterns – have impacts of varying degrees to each asset class studied – airports, seaports, and toll roads. Table 1 summarizes extreme weather events and their impacts on each asset class. For a more detailed description of the specific impacts on the physical infrastructure and suggested resilience measures, please see Appendix E for impacts on seaports, Appendix F for impacts on airports, and Appendix G for impacts on toll roads.

Table 1. Extreme Weather Impacts by Asset Class

Temperature	Sea Level	Storm Intensity and Frequency	Extreme Temperatures/Wildfires	Wind direction and speed	
(-)	(-)	(-)	(-)	(-)	Airport
nil	(-)	(-)	nil	(-)	Seaport
(-)	(-)	(-)	(-)	nil	Toll Road

(-) in the second table denotes an adverse factor to that asset. For example, wildfires are detriments to airports and toll roads, but likely not to seaports

Asset Productivity

An apparent effect of climate change on transportation assets pertains to the productivity of those assets. In some cases, the effect on productivity is nil. In some cases, it is negative. In rarer cases, it is positive. Climate change manifests in a few ways: rising mean temperatures, rising sea levels, increased annual precipitation and flooding, accelerated erosion, and increased frequency and severity of storms are the most familiar. Some areas, however, experience less familiar climate change effects: decreased annual precipitation, winter storms in previously temperate climates, and changes in local wind patterns, to name a few. It is important to note that these effects are least pronounced at the Equator, becoming more pronounced with latitude north and south (NASEM, 2019).

Paved surfaces are both the most important part of the transportation assets under review (airports, seaports, and toll roads) and the most vulnerable to a changing climate. Extreme heat can melt asphalt, damaging tires and compromising the integrity of the paved surface. Flooding and winter precipitation can render these areas unusable, representing a complete albeit temporary compromise of productivity. Paved surfaces, of course, come in various forms and functions. It is this diverse nature of paved infrastructure that instills its dual nature of a) providing access to some transportation facility or b) being (part of) the transportation facility itself, and hence makes it the most important physical component of any airport, seaport, or toll road.

Large transportation facilities may have agreements with local environmental agencies regarding municipal water quality. In the case of flooding and overloaded stormwater systems, frequent incidents of chemical (oil, fuel, de-icing fluid, etc.) seepage may embroil the facility operator in a legal dispute with local governments and other community stakeholders. (EPA, 2020) Water quality compliance is a set of agreed-upon measures of pollution that the transportation facility may not legally exceed. While this is not specifically a productivity issue, it is still a detriment to the operator’s credit risk. Legal action may reduce some productivity of the transportation asset.

Increased drought conditions also pose threats to productivity, especially inland. While drought is unlikely to exist at seaports (the opposite situation – a rising sea level – is more of a threat there), it again may compromise the integrity and efficacy of asphalt surfaces. Asphalt is malleable, making it more reactive to its physical environment than concrete. When asphalt heats, it loses solidity and forms under heavy vehicles. When it cools, it becomes brittle. In a drought, soil contracts, sometimes filling just 25% of its normal volume. This creates voids underneath pavement. As the asphalt above becomes brittle itself, vehicle weight (or simple loss of integrity) cracks the surface as it settles onto the reduced soil below. Nearby foliage will also reach farther for groundwater to survive, causing further soil contraction and thus exacerbating pavement cracking (Hill, 2016). Significant pavement cracking is a hazard to vehicle tires and, therefore, safety. A lost section of a roadway reduces its productivity and is compounded when maintenance crews must close more of the road to safely repair the affected area. Please see Appendix H for a further discussion on asset productivity.

Asset Demand

Demand volatility determines a transportation asset owner/operator's creditworthiness. Demand is the second piece in the credit-resilience puzzle, being influenced in part by climate change effects, and itself influencing non-recourse bond quality. Simply put, if climate change has zero probability of affecting some transportation assets, then demand is purely a market function. Yet, transportation being the interdependent and interwoven synaptic system that it is, there is not one seaport, airport, or toll road that will not feel the demand effects of climate change and face adaptation costs at some point.

At the most basic level, transportation assets located in regions more negatively impacted by climate change will see heightened demand volatility, while those located in regions less affected (or even positively affected) by climate change will enjoy more consistent, if not increasing, demand. What about transportation's interdependence? This poses a complexity above the base case. Those assets that are served primarily by demand from negatively impacted regions are on a precipice – will business at the afflicted origin decrease demand for the destination, or will residents of the afflicted region be more propelled to escape to the destination? Will both occur and change the nature of the destination's demand, i.e., a switch from business to leisure travel? Surely this would introduce volatility as leisure travel is more seasonal than business travel. Additionally, leisure travel tends to be anchored by weekends whereas business travel is more evenly distributed throughout the week. What about assets served primarily from environmentally thriving regions? Will they enjoy consistent demand levels or lose market share to some re-discovered place?

According to Earth's Future report on trade growth and port demand through 2050 under four combinations of climate policy interventions and global temperature increases, all scenarios lead to increased traffic through ports, requiring doubling or quadrupling port areas. (Earth Future, 2020). In addition, the Marine Policy concluded in their study about the evolution of maritime transport demand in response to global climate change mitigation, that trade will increase to between two and four times the 2010 value by 2050; however projections for containerized trade are a cautionary reminder to the sector that it cannot assume previously observed levels of growth to persist. Projections also suggest that markets for goods may saturate, mature further, or shift to new, less globalized, business models, particularly in more established markets, with a corresponding impact on trade. (Marine Policy, 2019).

Asset class implies much about demand volatility in the face of climate change. Toll roads, for example, both benefit and suffer from their design variation. Some are short and primarily service commuters and local traffic; some are long and serve as economic backbones for entire interstate regions. Some, independent of length, monopolize automobile access between two land masses – like toll bridges, tunnels, and causeways. Those most relied upon for timely commuting, cargo transport, and access between land masses should theoretically enjoy the steadiest long-run demand, regardless of climate. This is because these toll roads are central to local and regional transportation systems. Toll roads likely to experience the most demand volatility are express/HOT lanes, and those that are only tolled at certain times of day. Usually, cordon pricing occurs over short distances in densely populated areas, where non-tolled alternatives are plentiful.

Runway length is also a concern for many airports in the United States. Runway length is indicative of real estate – generally, if an airport sits on more land, it will have longer runways. More constrained airports will often have shorter runways, like New York's LGA, Washington's DCA, and Chicago's MDW. As mentioned in the section on asset productivity, rising mean temperatures because of climate change may render some airport runways unusable in their status over the next few decades. The warmer the air temperature, the more velocity is required to generate enough lift to become airborne. Heavier aircraft, naturally, also take longer to become airborne. At airports with shorter runways, airlines may have to reduce payloads or reduce aircraft size (if possible) to maintain safety (Coffel et al., 2017). As airlines attempt to maximize passengers and minimize flights, allowable aircraft size may change. This assumes a) that the airline has smaller planes to use and b) enough gate space and landing slots are available to accommodate the additional frequencies required to keep daily supply constant under steady demand. If one of these conditions cannot be met, the airline will likely end service to that airport, underscoring the asset's vulnerability. To ensure the airport's long-term passenger demand can be met, costly runway expansions will likely have to be completed, including land reclamation in the process. Please see Appendix I for a further discussion on asset demand.

Analysis of Official Statements

Official bond issuance statements are submitted by asset owners or developers to obtain a bond rating from the three major credit rating companies (e.g., Fitch Ratings, Inc. Moody's Investor Services, and Standard and Poor's). The ratings agencies evaluate the statements along with other data provided by the bond issuer to support the rating given for the asset in question. The task was to develop an appropriate investor framework for assessing the resilience of airports, seaports, and toll roads and how they were impacted by the changes in climate. Several airport, seaport, and toll road official statements were reviewed to determine if and to what extent each of them addressed the topic of climate change and resilience measures. The team used the Electronic Municipal Market Assess (EMMA) site to locate the official statements. The search methodology was to look for statements in the issuer name (e.g., San Francisco), if known, or description (e.g., airport). Once a listing was provided, the official statement was selected. In reviewing the statements, the documents were scanned for key words and phrases, including "climate, weather, temperature, resilience, and natural disasters." "The full faith and credit of neither the State nor any political subdivision thereof is pledged to the payment of or as security for the Series 20XX Bonds" phrase implies that the borrower has no recourse to obtain repayment for a failed venture. Further the team focused on non-AMT vs AMT funding bonds although many had a combination of each as part of the bond package. As stated earlier, non-recourse debt is riskier for the lender and is typically given a lower rating by the rating companies.

One of the key findings from review of the official statements was that a significant number of them did not address the long-term effects of climate change (and the resiliency of that asset to extreme weather events). Each official statement was reviewed for keywords such as "climate change, global warming, weather," and any related weather events to that particular asset class. Most official statements contained some mention of extreme weather and/or talk of climate change.

However, several official statements mentioned natural disaster response for immediate handling of the situation. For example, the Florida Turnpike official statement did not discuss long-term impacts of the increase in intensity of hurricanes but did discuss insurance regarding damage and the suspension of tolls. They even mentioned that an extreme weather event was likely to significantly impact the productivity and demand of the toll roads, as well as the revenue potential.

Several other official statements mentioned the fact that climate change is likely to increase in adverse effects to operations but there is no immediate plan of action. The Port of Houston Port Authority of Harris County official statement mentions the vulnerability due to extreme climate conditions and sea level rise, and "recognizes the urgency to allocate more financial resources to address these vulnerabilities," but does not extensively outline a specific climate plan of action.

Some official statements contained significant content on the impact of climate change and the resilience of the infrastructure. For example, Massport, in charge of operations at the Boston Logan International Airport (BOS) included a section outlining the 25–100-year climate change assessment and several environmental studies regarding the airport which is located adjacent to the Atlantic Ocean. Their primary concern is sea level rise and increased precipitation.

Asset managers are much more concerned with resilience from a demand perspective – for example, how to sustain current traffic levels – and management of natural disaster responses, as is seen in the Florida Turnpike Official Statement. Other asset managers do include the long-term implications of climate change and resiliency but do not have an immediate plan in place. It is more common to see a 5-year climate plan rather than a 50–100-year resilience plan more aligned with the design life of the asset.

Stakeholder Interviews

About the Interviews

This section summarizes information from interviews conducted with stakeholders on transportation resilience. Seven executives from the US DoT, three state DoTs, one transportation research organization, and one investment company were interviewed. Participants were asked questions about their past and current roles working within the transportation or investment sectors, how they would approach assessing and measuring resilience, benefit-cost of resilience investments, and future resilience challenges they foresee. A full list of interview questions and the interview recruitment memo can be found in Appendix C. The objective of the interviews was to gain an understanding of the current transportation resiliency practices, challenges, and frameworks/metrics.

Themes From the Interviews

- Unity of Effort: In the last five years, DoTs have established offices with the of mission looking at resiliency across sectors but lack unity of effort between departments, academia, and the public-sector to develop a feasible means to achieving resilience.
- Transition Risk: In the context of climate change and resilience, transition risk is the inherent risk and biggest challenge in changing strategies, policies, or investment strategies. Transition risk is the "risk that results from changing policies, practices, and technologies that arise as societies work to decrease their reliance on carbon" (Aquaoso, 2020)
- Agreement on How to Achieve Resilience: There is not a widely accepted practice to measure the resilience to mitigate risks and better inform investment strategies.
- Quantifiable Information: There is a lack of clear, comprehensive, and quantifiable information on the impacts of climate change to transportation assets.
- Investment Priorities: Depending on the type of organization, risks, geographical location, and available resources, the level of priority given to investing in resilience varied.

Existing Resilience Frameworks

This section provides a summary of the frameworks reviewed. Figure 9 provides the generalized steps in the resiliency planning process most of these frameworks identified in one way or another. Each of these frameworks provide a methodology was considered in developing the proposed recommended framework at the end of this report.

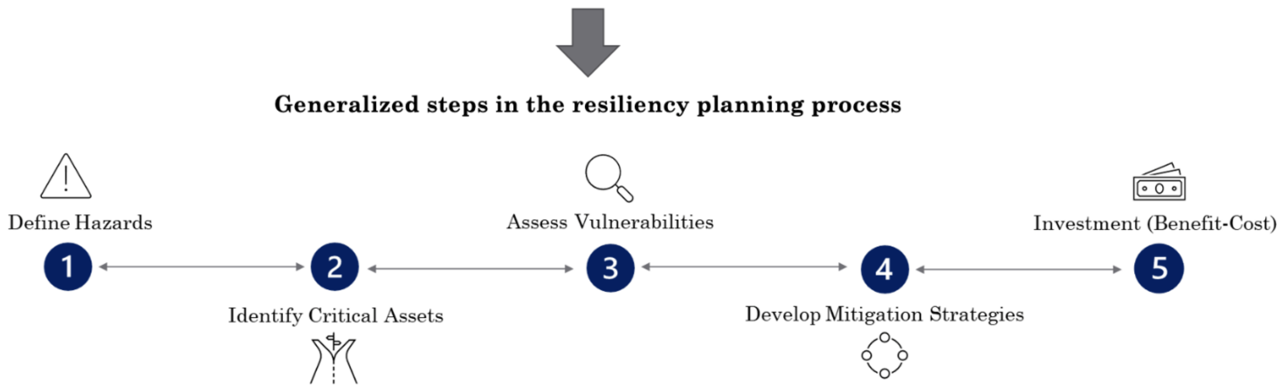

Figure 9. Existing resilience framework process outline

U.S. Climate Resilience Toolkit | U.S. Climate Resilience Toolkit

This toolkit provides the Steps to Resilience framework which describes a methodical approach communities can use to identify their valuable assets, determine which climate-related hazards could harm them, and then identify and take effective actions to reduce their risk.

World Bank's Resilience Rating System: A Methodology for Building and Tracking Resilience to Climate Change

To better monitor adaptation and resilience-related action, the World Bank's Action Plan on Climate Change and Resilience is committed to creating a Resilience Rating System (RRS) to complement existing methodologies on tracking climate-related finance3 and increase ambition for climate-aligned development. The main objectives of the RRS are to:

- Better inform decision makers, client countries, and other stakeholders.
- Create incentives for more and better climate adaptation.
- Identify best practices.
- Provide guidance on ways to incorporate appropriate risk reduction measures into project design.

Climate Resilience Framework (ISET International)
The Climate Resilience Framework (CRF) is an analytical, systems-based approach to building resilience to climate change. The goal of this structured framework is to build networked resilience that can address emerging, indirect, and slow-onset climate impacts and hazards.

Infrastructure Resilience Planning Framework (IRPF) (cisa.gov)
CISA's Infrastructure Resilience Planning Framework (IRPF) enables the incorporation of security and resilience considerations in critical infrastructure planning and investment decisions. It does this by helping communities and regions to (1) understand and communicate how infrastructure resilience contributes to community resilience; (2) identify how threats and hazards might impact the normal functioning of community infrastructure and delivery of services; (3) prepare governments, owners and operators to withstand and adapt to evolving threats and hazards; (4) integrate infrastructure security and resilience considerations; and (5) recover quickly from disruptions to the normal functioning of community and regional infrastructure.

Resilience Framework (dhs.gov)
This framework has a six-step process for incorporating continuity and resilience readiness into critical infrastructure assets to ensure DHS can sustain its mission essential functions in times of normal operations, threats, and disasters. The framework focuses on four critical infrastructure areas: energy and water, facilities, information and communication technology, and transportation.

Climate-Resilient Development A Framework for Understanding and Addressing Climate Change
This framework has been written for a broad audience. It provides input to other analyses undertaken in development strategy, and project designs.

OECD Guidelines for Resilience Systems Analyze How to analyze risk and build a roadmap to resilience
In this document you will find a step-by-step approach to resilience systems analysis, a tool that helps field practitioners to:

- prepare for, and facilitate, a successful multi-stakeholder resilience analysis workshop
- design a roadmap to boost the resilience of communities and societies
- integrate the results of the analysis into their development and humanitarian programming

Federal Highway Administration (FHWA), Climate Change Adaptation Tools for Transportation | U.S. Climate Resilience Toolkit
This site provides resources for assessing impacts of climate change on transportation infrastructure. These include (1) the CMIP Climate Processing Tool (provides relevant statistics for transportation planners), (2) the Sensitivity Matrix (documents the sensitivity of roads,

bridges, airports, ports, pipelines, and rail to 11 climate impacts), (3) the Guide to Assessing Criticality in Transportation Adaptation, and (4) the Vulnerability Assessment Scoring Tool (assesses transportation systems vulnerability to climate stressors).

Findings

Key Findings and Recommendations

1. **Measuring Transportation Resilience**
    a. **Finding:** There is not a widely accepted practice for measuring resilience of transportation infrastructure to mitigate risks and inform investment strategies.

2. **Climate Change Resilience Disclosures in Official Statements**
    a. **Finding:** Over the last ten years, attention to climate change resilience in official statements has improved significantly but requires more comprehensive information on the impacts of climate change on transportation assets.

3. **Expected Benefits of Resilience Investments**
    a. **Finding:** Typically, transportation projects that have invested in resilience do so for the next five-years with a focus on immediate natural disasters and the most likely security threats due to limited resources and competing priorities.

Framework

The recommended framework for analysis of seaport, airport, and toll road infrastructure project resilience to climate change effects is a two-part system. Part One is a checklist consisting of criteria (general and specific) pertaining to the project type under examination, climate-related risks at the project site, and the asset's overall productivity in its regional market and nationwide transportation system. The framework is based on the methodology summarized below in Figure 10.

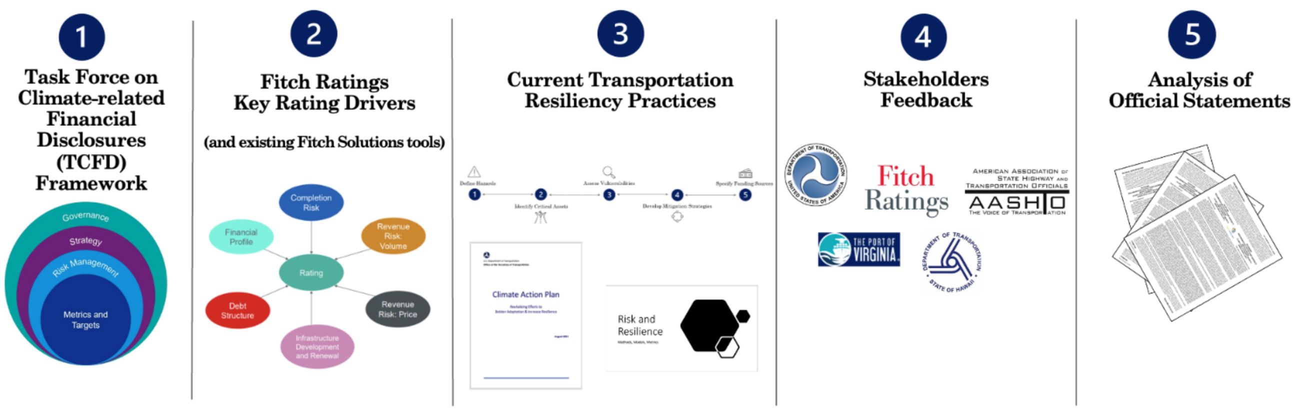

Figure 10. Recommended framework analysis

It is proposed that Fitch and other stakeholders in the credit rating process incorporate climate resilience into their existing rating framework, summarized in Figure 11 below.

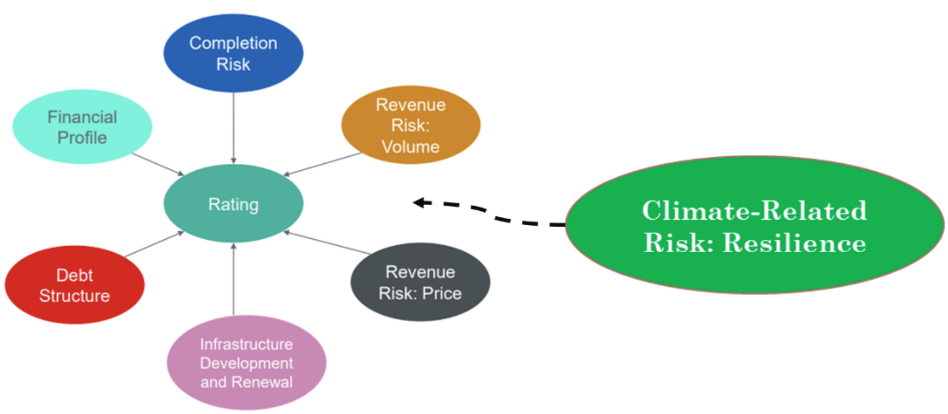

Figure 11. Illustration of climate-related risk into existing credit rating framework

Part Two takes the criteria from Part One and synthesizes them into a scatterplot diagram, Figure 12 below, balancing the relative climate change risk and resilience thereto of the project at hand. The diagram has four general regions bucketing the relative creditworthiness of the project:

- Region I (upper right): High-risk, high-resilience projects
- Region II (upper left): Low-risk, high-resilience projects
- Region III (lower left): Low-risk, low-resilience projects
- Region IV (lower right): High-risk, low-resilience projects

Responses from Part One sections “Project Type”, and “Asset Productivity” are weighed by the assessor and translated into y-values on the scatterplot. Responses from Part One section “Climate-Related Risks at Project Site” are weighed by the assessor and translated into x-values on the scatterplot. The coordinate pairs will fall somewhere within each quadrant on the graph, with relative location underscoring the continuous nature of the risk-resilience balance. Ceteris paribus, projects falling in Quadrants II and III should be the most creditworthy, while those falling in Quadrant I should still maintain investment-grade status. Projects falling in Quadrant IV, ceteris paribus, should be the least creditworthy given long-run climate change predictions.

The scatterplot was chosen because it is the optimal method for visualizing the nearly infinite combinations of climate change risk and resilience for seaport, airport, and toll road projects. The scatterplot was chosen over the alternate “heat map” or “heat wave” diagram because a scatterplot better fits singular and plural data points (transportation projects), whereas the “heat map” or “heat wave” is better assembled when comparing multiple data points.

Part One: Assessment of Project (via Official Bond Issuance Statement and Other Research)

By responding to each criterion below, the assessor will lead themselves to the quadrant-based visual representation of the asset’s resilience to climate-related risks.

1. PROJECT TYPE
   - **a. Asset class**: airport, seaport, toll road, other
   - **b. Issuer**: regional transportation authority, city, state, private entity, conduit, other
   - **c. Bonds issued**: $ amount
   - **d. Recourse** status of bonds issued

2. CLIMATE-RELATED RISKS AT PROJECT SITE
   - **a. Location**: coastal, inland, elevation, latitude, spatially constrained/room to grow, etc.
   - **b. Type** of climate-related risks to site: mean temperature, flooding, hurricanes, wildfires, etc.
   - **c. Impact** of high-probability climate-related risks: total asset shutdown, partial asset closure, user inconvenience, etc.
   - d. (Based on 2a, 2b, 2c) Overall climate-related **risk level** at project site: high, medium, low

3. ASSET PRODUCTIVITY
   a. Evidence of climate change **resilience** either in practice (proven) or in official bond issuance statement (planned)
   b. Overall asset **condition**: good, fair, poor
   c. **Demand** resilience (two-sided: individual users and commercial/public carriers)
      - Asset's <u>centrality</u> to its market: substitutes, complements, expendability
      - <u>Strength</u> of local/regional economy
      - Necessary economic and political <u>conditions for full operation</u>: tourism, business, military activity, international trade, etc.
      - Demand <u>forecasts</u>
      - <u>Adaptability</u> to changes in markets and technology

Part Two: Visual Representation of Asset's Resilience to Climate-Related Risks

Table 2. Climate Resiliency vs. Risk Quad Chart

	Low Risk	**High Risk**
High Resilience	Geographically the project is in an area **<u>not vulnerable</u>** to extreme weather events The preliminary engineering report shows a **<u>high</u>** level of resilience against extreme weather Credit Neutral-Negative	Geographically the project is in an area **<u>vulnerable</u>** to extreme weather events The preliminary engineering report shows **<u>a high</u>** level of resilience against extreme weather Credit Neutral-Positive
Low Resilience	Geographically the project is in an area **<u>not vulnerable</u>** to extreme weather events Preliminary engineering shows a **<u>low</u>** level of resilience against extreme weather Credit Neutral-Positive	Geographically the project is in an area **<u>vulnerable</u>** to extreme weather events The preliminary engineering report shows a **<u>low</u>** level of resilience against extreme weather Credit Negative

Table 2 compares the four different general outcomes when comparing high/low risk and high/low resilience for an asset. It is important to recognize that risk and resilience for an asset is only one of several different factors that affect credit rating – a high risk project could have several other factors that make up for this perceived area of risk.

- A high risk, high resilience project has potential to be a good investment because even though the asset is located in a vulnerable region to climate change, the engineers have designed that asset adequately to withstand any extreme weather events. Engineers and credit raters must determine if the risk exceeds the resilience.
- A low risk, high resilience project has potential to be an ok investment because the asset is not located in a vulnerable region to climate change and exceeds the ability to withstand extreme weather events. However, a low risk, high resilience project has potential to be a bad investment because of overspending on unnecessary protection measures against extreme weather events.
- A high risk, low resilience project has potential to be a bad investment because the asset is located in a vulnerable region to climate change, and engineers have not adequately designed that asset to withstand any extreme weather events.
- A low risk, low resilience project has the potential to be a good investment because the asset is not located in a vulnerable region and does not need to withstand extreme weather events, resulting in cost savings. However, there needs to be a minimum threshold for acceptable resilience even in low-risk regions.

Figure 12 below builds upon Table 2, using four different examples from the toll road asset class, highlighting examples of a low-risk/low-resilience project, low risk-high-resilience project, high-risk/low-resilience project, and a high-risk/high-resilience project. The green color gradient represents projects that pose a lower risk due to climate change than the red color gradient.

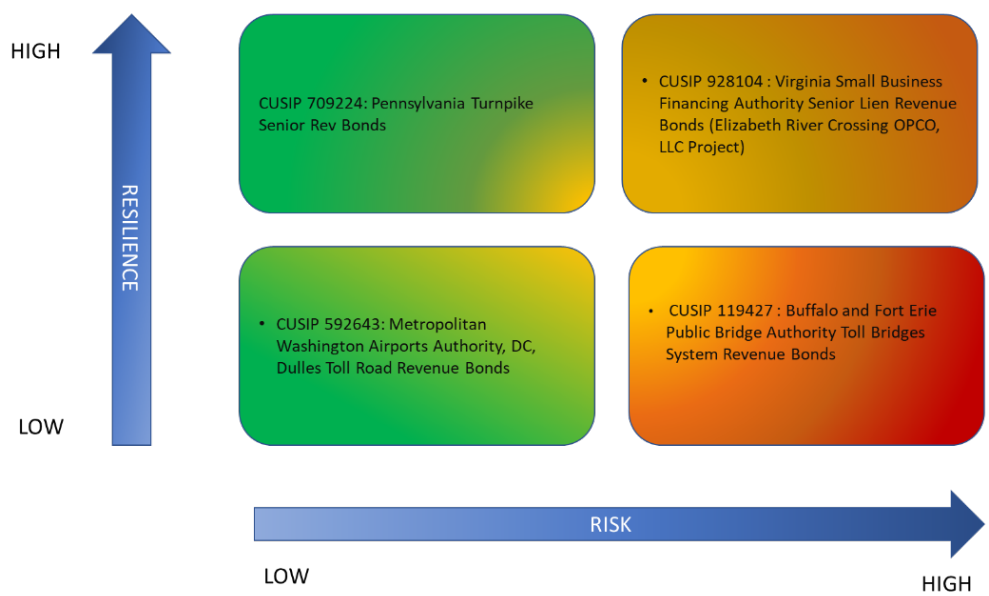

Figure 12. Resilience vs. risk graphic with four toll road examples

Conclusions

The purpose of this report was to provide Fitch Ratings with findings and recommendations that can inform their approach to incorporating climate resilience into their transportation sector. In addition, a transportation resilience framework was developed using a four-phase approach to help Fitch Ratings assess the climate change resilience of airports, seaports, and toll roads. The framework is a two-part system. The first part consists of evaluating the project type, the climate-related risks at the project site, the assets productivity in the market and their strategic response planning. The second part is a visual representation in a scatterplot diagram balancing the relative climate change risk and resilience thereto of the project at hand, using the gathered information from Part One.

The key findings were that there is not a widely accepted practice to measure the resilience of transportation infrastructure to mitigate climate-related risks, to better inform investment strategies in the transportation and financial sectors. Additionally, the attention to climate change resilience in the official statements has significantly increased over the last ten years with investors requiring more clear, comprehensive, and quantifiable information on the impacts of climate change on transportation investments. Most transportation planning organizations are investing in resilience for a short-term period due to limited resources and market competition. To address these concerns, the recommendations include to develop a quantifiable project climate-related risk resilience metric, seek more engagement from stakeholders during climate change resilience planning process, and prioritize investments that incorporate long term climate change resilience strategy.

Appendices

Appendix A: Abbreviations

AASHTO	American Association of State Highway and Transportation Official
IIJA	Infrastructure Investment and Jobs Act (2021)
NRSRO	Nationally Recognized Statistical Rating Organizations

Appendix B: Interview Recruitment and Protocol – Interview Recruitment Memo

SCHAR School of Policy and Government
GEORGE MASON UNIVERSITY

February 3, 2022

To Whom It May Concern:

Graduate students in the Master's in Transportation Policy, Operations and Logistics program at George Mason University are conducting a study related to the resilience of airports, seaports and toll roads to climate change.

I am writing to request your cooperation with the study team identified below in answering questions and providing background materials and referrals to other individuals with relevant knowledge and experience.

The study team consists of the following individuals:

Gale Brown-Neuhaus

Chris Harloe

David Kwekham

George Lu

Joe Quenga

Will Snyder

They are working with Scott Zuchorski, Managing Director, Head of North America Infrastructure and Project Finance.

I am the faculty supervisor of this project. Please feel free to contact me if you should have any questions by email at jgifford@gmu.edu or by phone at +1-202-669-9228.

Thank you in advance for your cooperation.

Sincerely,

Jonathan L. Gifford, Professor
Director, Center for Transportation Public-Private Partnership Policy

Cc: Scott Zuchorski

Schar School of Policy & Government
George Mason University
3351 N. Fairfax Drive MS3B1
Arlington, VA 22201 U.S.A.

Appendix C: Interview Protocol & Informed Consent – Interview Questions

1. Can you describe your current role and provide a brief summary of your past experiences?

2. What projects have you worked on related to assessing resilience, risk management, and/or vulnerability evaluation?

3. How would you or your organization define resilience/transportation resilience?

4. How would you or your organization approach measuring resilience?

5. Do you know of any initiatives that are studying and addressing transportation resilience?

6. What would be an important investment criterion in assessing the resilience of an infrastructure or project finance of transportation entities?

7. What would you want airports, seaports, or toll roads to be resilient to?

8. Has your organization incorporated resilience into transportation planning?

9. Have you worked on or know of any transportation projects that have incorporated resilience?

10. Do you know of any other points of contact that may be beneficial to our research project?

Appendix D: Discussion of Climate Conditions Found in Each Region of the United States

Table 3. Summary of Climate Conditions Found in Ten US Climate Regions

U.S. Region	Climate Conditions
Northeast	Extremes of cold, snowy winters and warm to hot, humid summers. Increases in rainfall intensity. Increases in total precipitation are expected during the winter and spring but with little change in the summer. Projected increases in temperature, acidification, storm frequency and intensity, and sea levels are of particular concern for coastal and ocean ecosystems. Impacts from storms and sea level rise will vary at different locations along the coast. Climate-related disruptions will only exacerbate existing issues with aging infrastructure. Sea level rise has amplified storm impacts.
Southeast	Sea level rise, increasing temperatures, extreme heat events, heavy precipitation, and decreased water availability. Flooding increases stress on infrastructures. Sea level rise and extreme downpours as well as increased exposure to dangerously high temperatures with accompanying humidity are of increased concern.
Southern Great Plains	Dramatic weather patterns: Hurricanes, flooding, severe storms with large hail and tornadoes, blizzards, ice storms, relentless winds, heat waves, and drought. Significant stress to existing infrastructure. Climate varies from Arid in the high elevations to humid on the southern border. Vulnerable to periods of drought and periods of abundant precipitation. Vulnerable to hurricanes, sea level rise and tropical cyclones. Significant flooding and rainfall events followed by drought.
Southwest	Hottest and driest climate in the US. Climate transitions from deserts and grasslands in hotter and lower elevations in the south to forests and alpine meadows in cooler, higher elevations in the north. Natural and human-caused wildfires. Sea level rise, storm surges, ocean warming, and ocean acidification are altering the coastal shoreline and ecosystems.
Northwest	The region has warmed substantially—nearly 2°F since 1900. The Northwest is projected to continue to warm during all seasons under all future scenarios, although the rate of warming depends on current and future emissions. Wildfire infrastructure damage is abundant. Years of abnormally low precipitation and extended drought conditions persist. El Niño winter storms contributed to storm surge, large waves, coastal erosion, and flooding in low-lying coastal areas.
Northern Great Plains	The impacts of climate change throughout the Northern Great Plains include changes in flooding and drought, and rising temperatures.

	Additionally, changes in precipitation patterns, warmer temperatures, and the potential for more extreme rainfall events will likely occur.
Midwest	Trends toward warmer, wetter, and more humid conditions. Increasing precipitation, especially heavy rain events, has increased the overall flood risk.
Alaska	Frontlines of climate change and among the fastest warming regions on Earth. Thawing permafrost, melting glaciers, and the associated effects on Alaska's infrastructure. Lack of sea ice also contributes to increased storm surge and coastal flooding and erosion, leading to the loss of shorelines. A warming climate is also likely to increase the frequency and size of wildfires.
Hawaii & US Affiliated Pacific Islands	Includes tropical cyclones, coastal flooding, and erosion. Air and sea surface temperatures continue to increase. Sea level rise, ocean acidification, and extremes such as drought and flooding persist.
US Caribbean	Vulnerability to drought due to decreased rainfall, sea level rise, coastal erosion. Increase in the intensity of tropical storms including hurricanes.

Table source: Fourth National Climate Assessment (globalchange.gov)

Appendix E: Impacts of Climate-Related Extreme Weather Events for Seaports

Impacts

- Seaports are subject to sea level rise, increased storm intensity and frequency (especially hurricanes/tropical storms), and changes in wind direction and speed
- Coastal ports and harbor facilities will be affected by increased intense precipitation and mean sea level rise. The frequency and intensity of these storms are likely to increase and cause extreme waves and storm surges. This increases the probability of damage to terminal facilities, infrastructure, intermodal freight rail terminals, and equipment and would cause flooding of pavement bases and bridge supports. There is a large variation in sea level rise predictions and as such are framed as barriers to climate resilient seaports resulting in the immediate need for looking strategically to safeguard against climate change.(Finley & Schuchard, n.d.)
- The navigability of shipping channels is also likely to change. Some channels may be more accessible to shipping farther inland because of sea level rise, and others could be adversely affected by changes in sedimentation rates and the location of shoals.
- More frequent interruptions of transportation services provided by the infrastructure and higher costs of maintenance and operations are expected. Shipping delays and disruptions to the supply chain will follow.

Resilience Measures

- Seaports with weather/climate related considerations in planning, design and construction of infrastructure are considered less vulnerable to sea level rise.
- Seaports received or expected to receive financial or other assistance in the implementation of adaptation measures from government/non-government sources are considered less vulnerable to sea level rise.
- Seaports equipped with real time monitoring of waves and tides are considered less vulnerable to sea level rise.
- Typical mitigation measures for rising water levels include dikes and/or elevating the asset site through fill. Both measures are significant efforts that also must consider impacts on ingress and egress routes to the asset for productivity.

Major US Seaport Locations and Weather Patterns

Figure 13 displays/locates the nine major seaports along the US coasts. All of these ports deliver essential goods to consumers, ship exports and support millions of jobs (Quinn & Oritz, 2020) A tabular synopsis of the typical climate conditions at these ports is shown in Table 4. The table shows the highest temperature month, lowest temperature month, windiest month, wettest month, and the average precipitation at these locations.

Figure 13. Location of nine major seaports in the United States

Image Source: 2020 U.S. Seaports Outlook Report | Colliers

Table 4. Climate Conditions of Nine Major United States Seaports

US Seaports	Low Temp (Month)	High Temp (Month)	Windiest Month	Wettest Month	Average Precipitation
Port of NY/NJ	34˚F (January)	77˚F (July)	February	June	24.35 inches/year
Port of VA	42˚F (January)	81˚F (July)	March	July	21.32 inches/year
Port of Charleston, SC	49˚F (January)	83˚F (July)	April	August	23.73 inches/year
Port of Savannah, GA	51˚F (January)	83˚F (July)	March	August	21.67 inches/year
Port of Houston, TX	55˚F (January)	85˚F (July)	February	June	19.01 inches/year
Port of Los Angeles, CA	58˚F (December)	75˚F (August)	May	February	3.83 inches/year
Port of Oakland, CA	50˚F (January)	64˚F (August)	May	December	4.83 inches/year
Port of Seattle, OR	42˚F (August)	68˚F (December)	March	November	15.03 inches/year

Table source: timeanddate.com

Appendix F: Impacts of Climate-Related Extreme Weather Events for Airports

Sea Level Rise Impacts

- Sea level rise and storm surge allow seawater to damage airport infrastructure and will increase flood risks on ground transport links that disrupt airport accessibility, operations or cause temporary airport closure.

Sea Level Rise Resilience Measures

- Typical mitigation measures for rising water levels include dikes and/or elevating the asset site through fill. Both measures are significant efforts that also must consider impacts on ingress and egress routes to the asset for productivity
- Airports located in areas that are away from coasts or situated at higher ground level are considered less vulnerable to sea level rise.
- Airports that are protected by engineering structures such as levees are considered less vulnerable to sea level rise.
- Airports equipped with dewatering infrastructure, such as pumping systems, are considered less vulnerable to sea level rise.

Intense Precipitation and Hurricane Impacts

- Increase in rainfall and more intense storms will increase the risks of flash flooding, inundation of infrastructure, and disconnection to ground transportation networks. Costs of maintaining the airport facilities, runways, mobile or fragile equipment would increase due to intense precipitation. Flight delays, cancellations, and temporary airport closure due to heavy storm events will negatively impact airport operations and productivity. Hurricane-force winds create dangerous landing conditions for aircraft takeoff and landing.

Intense Precipitation and Hurricane Resilience Measures

- Airport facilities and accompanying infrastructure considering higher drainage design standards are considered less vulnerable to intense precipitation.

Extreme Temperature Impacts

- Changes in average and extreme temperatures cause exceedance of design standards resulting in heat damage on airport surfaces (especially asphalt), take-off weight restrictions, and potential needs of longer runways. Significant changes in temperature ranges airport facilities costs. Permafrost thawing (in northern latitudes) may lead to ground instability and comprise infrastructure integrity.

Extreme Temperature Resilience Measures

- Airports located in regions with a more moderate climate are less likely to suffer from extreme temperature impacts to infrastructure.

- Design materials for airport facilities/infrastructures (asphalt, concrete, and steel) that are sustainable to larger range of temperature is considered less vulnerable to extreme temperatures.

Change in Local Wind Patterns Impact

- Airplanes landing at airports with extreme crosswind conditions are subject to aircraft destabilization potentially causing a crash on the runway. The increased winds would require the planes to be diverted to other nearby airports thereby increasing their planned demand at secondary facilities and decreasing demand at primary facilities.
- Not addressing increased windshear events decreases the productivity of aircraft.

Change in Local Wind Patterns Resilience Measures

- Airports located at areas that are subject to less interruption by changing wind directions and extreme high wind are considered less vulnerable to Changing wind.
- Long-term wind studies are conducted (or past wind observations are collected) prior to airport construction to determine an appropriate runway orientation
- Increased windshear events could require new technologies to mitigate the increased danger to aircraft.

Appendix G: Impacts of Climate-Related Extreme Weather Events on Toll Roads

Sea Level Rise Impacts

- Higher sea levels and increased storm surges will erode coastal roadway embankment and undermine bridge foundations. Encroachment of saltwater would lead to accelerated degradation of bridges and tunnels and reduce life expectancy, increase maintenance costs and potential for structural failure during extreme storm events[2].
- Higher sea level will also jeopardize efficiency of roadway drainage system resulting in more roadway flooding. Sea level rise and storm surge will increase the risk of major coastal impacts, including both temporary and permanent flooding of roads, bridges, and tunnels.

Sea Level Rise Resilience Measures

- Toll roads that are away from coastal areas or situated at higher ground level are considered less vulnerable to sea level rise.
- Toll roads that are protected by engineering structures, such as levees, are considered less vulnerable to sea level rise.
- Toll roads in sag areas or tunnels equipped with dewatering systems, such as pumping systems, are considered less vulnerable to sea level rise.
- Typical mitigation measures for rising water levels include dikes and/or elevating the asset site through fill. Both measures are significant efforts that also must consider impacts on ingress and egress routes to the asset for productivity.

Intense Precipitation Impacts

- Intense precipitation causes flooding that would impose a significant threat to toll road infrastructures. Flooding leads to massive obstruction of traffic, increased weather-related accidents, damage to roadway structures, and increased repair costs.
- Heavy precipitation and increased runoff on impervious surfaces can cause damage to tunnels, bridges, culverts, roads in or near flood zones, leading to disconnection of transportation networks that causes significant economic losses in a region.

Intense Precipitation Resilience Measures

- Toll roads that are away from flood zone or situated higher than flood elevation in a flood zone is considered less vulnerable to intense precipitation.
- Roadway networks with fewer flood zone crossings are considered less vulnerable to intense precipitation.
- Roadway infrastructure with hydraulic designs considering extra capability to accommodate high-magnitude storm events are considered less vulnerable to intense precipitation.

Hurricane Impacts

- Strong hurricanes create heavy precipitation, higher wind speeds, and higher storm surge and waves. Damages due to strong hurricanes include roadway flooding, displacement of bridge decks, signs, and overhead cables. Lighting and electrical disturbance could disrupt transportation intelligent highway systems' electronic infrastructure and signal communication systems.

Hurricane Resilience Measures

- Toll roads with an increased factor of safety against heavy precipitation and wind are considered less vulnerable to hurricanes.

Extreme Temperature Impacts

- High air temperature will increase the potential of permanent deformation in asphalt layers. Due to the traffic characteristics, such permanent deformation may accumulate on the wheel paths of the pavement (especially large load-bearing trucks) causing a major pavement distress called rutting. Low temperature will increase the potential of cracking in the pavement layer. The most critical (and common) cracking is fatigue cracking induced by repeated vehicle loads. Fatigue cracking may occur at normal to low temperature conditions but the lower the temperature, the more likely that such cracking will be developed.
- At extremely low temperatures, asphalt pavement may have a distress called low-temperature cracking. The cracking is caused solely by the thermal contraction of the pavement materials even without considering the effect of traffic loads.
- Extreme temperatures also impact bridges by exerting extra stress through thermal expansion and increased movement. Permafrost thawing would lead to increased slope stability, landslides and shoreline erosion damaging roads, bridges, and tunnels due to a foundation settlement

Extreme Temperature Resilience Measures

- Road and bridge surfaces which use pavement materials that can accommodate a larger temperature range/designed appropriately for extreme temperatures are considered less vulnerable to extreme temperatures.
- Roadway infrastructure designed and constructed with considerations of the extra loads from heavy vehicles due to thermal effects are considered less vulnerable to extreme temperatures.

Appendix H: Further Discussion of Productivity

Drought-stricken airports risk productivity loss because of runway pressure washing requirements (NASEM, 2012). When an aircraft lands, it leaves rubber deposits at the point of touchdown. Commonly known as "skid marks," these black streaks are plainly visible in satellite imagery at runway ends (and even on heavily used taxiways). Accumulation of aircraft rubber deposits reduces friction on the runway and poses a safety threat to landing and departing aircraft, especially in wet weather (Chen et al., 2008). As such, airports regularly clean runway touchdown zones via pressure washing, usually overnight for minimal operational interruption. The ability to continue this practice is vital to the airport's very usability. As such, enough water must be available (and affordable) to continue runway usage. The importance of pressure washing is heightened at airports with steady wind patterns, which induce a static operational direction – in other words, runways at airports with almost unidirectional winds are disproportionately worn at one end, requiring more frequent pressure washing – see satellite imagery of LAX for an example. Fortunately, inland (read: more drought-prone) airports tend to have variable winds, which should mitigate some of this productivity risk, but it is worth considering. Adaptation to prolonged and more frequent drought insists upon the strict use of non-potable water for non-potable functions, with consideration given to runoff and local biome health (NASEM, 2012).

In the opposite climatic situation, sea level rise and storm surges will continue to increase the risk of major coastal impacts on transportation infrastructure, including both temporary and permanent flooding of coastal transportation infrastructure. Mean global sea levels are expected to rise an additional one to four feet by the year 2100. (NCA, 2014). In fact, the chapter in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on North America identifies coastal flooding from expected sea level rise and storm surge, especially along the Gulf and Atlantic coasts, as one of the most pressing effects of climate change (Burkett, 2002 in Field et al., 2007). Hindrances to road and rail productivity will also increase with more frequent flooding. For example, Hurricane Sandy's storm surge produced nearly four feet of floodwaters throughout the port system of New York and New Jersey, damaging electrical systems, highways, rail track, and port cargo; displacing hundreds of shipping containers; and causing ships to run aground. Floating debris, wrecks, and obstructions in the channel had to be cleared for several days before ports could safely reopen. (NCA, 2014).

Appendix I: Further Discussion of Demand

Toll roads that are non-central (read: easily avoided) are viewed as a transportation luxury – in economic terms, they are a normal good. To introduce a point of purchase on a roadway especially with demand-variable pricing, travel on that roadway must be justifiable. Not only should the route save significant time compared to nearby alternatives, but it must also be in good condition. As such, climate resilience on non-central toll roads (such as Maryland's Route 200 Intercounty Connector) is paramount. If a non-central toll road regularly crumbles, cracks, and is filled with potholes because of cold, ice, or drought, motorists simply will not use it. Likewise, if this road buckles and melts in extreme temperature swings or is regularly covered in mudslides or floodwaters, motorists simply will not use it. The road will be a failure and the owner/operator's finances will be in peril unless they are assisted at the state or federal levels. Any non-recourse bonds issued by an owner/operator in this situation must be scrutinized for creditworthiness.

Owners and operators of toll roads that are central to the system (like the New Jersey Turnpike) have less incentive to keep the road and its facilities in excellent working condition – only adequate condition. The centrality of the asset alone is enough to propel steady long-run demand, and toll revenues should be enough to fund adequate maintenance. If the road monopolizes travel between two points (like the Verrazano Narrows Bridge connecting Staten and Long Islands at a modest, but not insignificant, E-Z Pass price of $6.55 as of April 2021), incentive to maintain the asset well is further reduced (MTA, 2021). This is because passage on the road requires less justification on the part of the motorist, as the motorist has no nearby alternatives.

If the road is central enough to the system, motorists will endure some level of climate resilience and maintenance neglect (and resultant traffic delays) so long as that route is still the most effective for their trips. This does not mean that the New York Metropolitan Transit Authority (MTA) can let the Verrazano Bridge crumble, or that its onramps and offramps can be underwater, but the pressure to fill every crack and pothole as on a luxury road (like MD-200) is not the same. The Verrazano Bridge, if maintained to the point of safe and uneventful passage, should never be a balance-sheet failure. Non-recourse bonds associated with central toll roads (or any central transportation asset) should, ceteris paribus, carry less credit risk.

Airports face similar demand volatility to toll roads, with asset centrality being the ultimate governor of long-run demand. However, airports do not only need to attract consumers, i.e., the flying public, they also need to attract tenants, i.e., airlines and fixed-base operators (jet charters). If tenants do not utilize the airport, neither will the flying public. While centrality is a factor in demand, airports cannot get by with subpar airside infrastructure, like toll roads can be filled with modest cracks and potholes, yet still be safe for automobile travel. Airplanes are multimillion-dollar pieces of equipment that may carry hundreds of passengers each, at extremely high speeds – they require excellent infrastructure conditions. This, combined with the fact that many airports are multimodal transport hubs and thus vital to regional economies, means that airport owners/operators must do more to promote climate resilience than toll road owners/operators.

Flooding from rising seas and/or increased annual precipitation can compromise efficiency by inundating runways and taxiways and can compromise safety by acting as inadvertent bird habitats and havens of infectious disease (NASEM, 2018). From a facility demand perspective, this is of more concern to an airline than to the general passenger. If airport operations are continually delayed by flooding issues, it will become less attractive for airlines and fixed-base operators to conduct their business there. The same goes for winter weather if snow/ice removal and de-icing equipment are insufficient. If issues compound and the supply of airplane seats at the field diminish, the travelling public will eventually catch on and lose interest in the airport as a place to begin and end their trips. Landside, flooding of access roads and parking facilities is also unacceptable. Combining just these two climate change effects (temperature and adjacent sea level) it becomes clear that inland airports with long runways (well-aligned with local winds) and efficient winterization assets should see the steadiest demand in the coming decades, and at that point should issue the most trustworthy non-recourse bonds.

Appendix J: Discussion of Mixed Impacts of Climate Change

One of the more peculiar changes in global climate is the change seen in the polar vortex. Warming at the poles pushes the polar vortex (the circular pattern of winds around each pole) outwards, towards the Equator. As a result, areas closer to the poles are experiencing somewhat milder winters, while areas closer to the equator are experiencing unprecedented winter weather. Texas is a notable example. Two days before Super Bowl XLV in 2011, north central Texas experienced an unusual winter storm that decimated travel in the Dallas-Fort Worth area, where the Super Bowl was to be held. At DFW Airport, snow removal and meager and mostly meant for clearing roadways. Crews could not keep the airfield clear of snow and ice during the storm, and residual cleanup was a painfully slow process. There was not nearly enough deicing equipment to meet demand. In response to the winter storm colliding with one of DFW's busiest historical travel periods, the airport more than doubled its snow and ice removal capacity, acquiring dozens of new airfield-specific (read: larger) plows and scrapers that would guarantee any runway clear in just 14 minutes. Numerous additional deicing trucks were also acquired (NASEM, 2012).

In February 2021, unusual cold and ice wreaked disaster on Texas' transportation and electricity networks. Transportation productivity was eliminated in much of the state, in part due to accumulated ice and in part due to a lack of electricity. Texas' electrical grid failure had a two-pronged effect on transportation infrastructure: first, much of it cannot run without electricity (especially when covered in unusual ice); second, widespread whiteouts eliminated travel demand, as work and leisure activity in much of the state was futile.

Closer to the North Pole, Alaska faces notable coastline erosion and settling, sometimes depleting up to 100 feet of shoreline per year. Flooding is overwhelming historically ice-protected areas and inducing thawing. This is at times destroying the already limited transportation infrastructure in remote villages, many of which are cut off from the rest of Alaska's transportation network and rely on small airstrips for the arrival of supplies. Where possible, runways and airstrip access roads require physical reinforcement or elevation to cope with the thawing and changing land underneath. In extreme cases, entire villages are being relocated because reinforcement is not possible or cost effective (NASEM, 2012).

Some localities, like Toronto, extract net benefits from milder winters. At YYZ (the city's primary international airport) the reduced need for snow/ice removal and aircraft deicing equipment, as well as the reduced need for landslides, snow and ice removal via road plows and salt/brine are producing large cost savings. Being inland, the airport is not vulnerable to coastline erosion or extreme land settling. YYZ's primary concern is a legal one regarding increased runoff and water quality in a bordering creek, which runs through many neighboring residential communities (NASEM, 2012). Perhaps a secondhand market is emerging for winter weather equipment across all transportation asset classes – a market of capital reallocation from newly thawing areas to newly freezing ones.

Standing water, as a result of thawing or flooding, also attracts birds. At airports, bird activity poses a serious threat to aircraft safety – a bird strike on takeoff or landing easily destroys jet engines and causes other fuselage damage. Loss of thrust during these critical phases of flight can compromise lift and is always an emergency. Climate scientists expect the increased flooding associated with climate change to cause an increase in bird strike/bird ingestion incidents (NASEM, 2019). When a departing aircraft makes an emergency return to its departure airport because of a bird strike, local airspace is restricted to provide priority handling and free maneuvering space to the afflicted aircraft. If the emergency aircraft returns safely, its arrival runway may be closed, quickly rippling delays through the national airspace system, causing an aggregate loss of productivity.

Appendix K: Official Statement Analysis for Airports

Metropolitan Washington Airports Authority - Airport System Revenue and Refunding Bonds - Series 2021A/B

CUISP #592647
06/02/2021
$899,625,000
Fitch Ratings "AA-"
Moody's Investors Service, Inc "Aa3"
S&P Global Ratings "A+"
Metropolitan Washington Airports Authority (msrb.org)

This Official Statement pertains to the Airports and the Airports Authority's operation of the Aviation Enterprise. The Airports could sustain damage and loss of use resulting from certain unexpected events (e.g., terrorist attacks, extreme weather events and other natural occurrence.) The Airports Authority has attempted to address these issues through insurance; however, it is uncertain if the coverage is or will be sufficient to cover claims in a timely manner. Global climate change effects include sea level rise, extreme temperatures and extreme weather events that will become more frequent due to GHG (greenhouse gas) and associated effects. These effects could cause more disruptions to service including long power outages and fuel shortages. Due to locations in near-coastal areas, operations may be at risk of substantial flood damage over time resulting in increased expectation for the Airports Authority's to mitigate climate change effects in the future resulting from climate related regulation changes. Dulles airport has one Crosswind Runway used primarily during periods of high winds.

California - Airport Commission of the City and County of San Francisco - San Francisco International Airport Second Series Revenue Bonds - Series 2022A/B/C

CUISP #79766
1/25/2022
$732,820,000
Moody's "A1"
Fitch "A+"
Airport Commission of the City and County of San Francisco (msrb.org)

This Official Statement speaks about the risk associated with Global Climate Change indicating numerous studies show sea levels are rising and extreme temperatures and weather events are more frequent and intense. San Francisco and the airport are both vulnerable to these events and associated impacts. These effects could in turn affect the passenger demand for the service, reducing travel globally or locally and affecting the infrastructure required. In 2019, the Airport partnered with other departments across the city to prepare a Hazards and Climate Resilience Plan to understand and address the potential impacts to reduce the severity of these impacts to the infrastructure and people. This document identified hazards, vulnerabilities, and consequences with proposed strategies to mitigate risks and adapt to unavoidable climate impacts. In 2020, a Sea Level Rise Vulnerability and Consequences Assessment was released describing the vulnerabilities to sea level rise and coastal flooding and the consequences anticipated for people, economy, and environment. Besides the direct impact studies, there are indirect adverse impact anticipated; however, they are outside the Airport's control (e.g., regulations at all levels,) aimed to curbing climate change effects that could impact operations and infrastructure as well as the finances of the Airport. The Airport is committed to protecting the environment through various sustainability initiatives and mentioned throughout this Official Statement.

Illinois - City of Chicago – Chicago-O'Hare International Airport - General Airport Senior Lien Revenue Bonds - Series 2022A/B/C/D/E

CUISP #167593
09/24/2020
$1,219,115,000
S&P Global Ratings "A" (negative outlook)
Fitch Ratings "A" (negative outlook)
Kroll Bond Rating Agency "A+" (negative outlook)
City of Chicago - Chicago O'Hare International Airport (msrb.org)

The Official Statement discusses major events beyond their control that will affect the airport demand if the events do happen. Many of these items are not direct climate change impacts or changes; however, they will affect the asset conditions, productivity, and demand. These areas include fire, flood, earthquake, epidemic, pandemic, adverse health conditions or other unavoidable casualties or acts of God, freight embargo, … pollution, unknown subsurface or concealed conditions affecting the environment, and any similar causes. The facilities are being updated and transformed over time; however, the Official Statement does not provide a detailed plan or outline for specific actions taken for potential impacts Climate Change impacts to the Airport facilities.

Texas - Cities of Dallas and Fort Worth, Texas – Dallas-Fort Worth International Airport - Joint Revenue Refunding Bonds - Series 2021A

CUISP #2350367
10/21/2021
$206,350,000
Fitch Ratings, Inc "A+"
Kroll Bond Rating Agency, Inc. "AA"
Moody's Investors Service, Inc. "A1"
Cities of Dallas and Fort Worth (msrb.org)

The Official Statement discussed at length the impact of COVID-19 Pandemic on the Airport which included passengers, operational data, aircraft operations, departures and destinations and passenger travel. The statement also included a short section on environmental, social and governance goals and the Airport's support for 14 of 17 of the United Nations Sustainable Development Goals. It further discussed the Airport has issued an annual ESG report since 2016. A more detailed discussion is contained on their website; however, that information is not incorporated by reference. No other climate information is contained in this Official Statement.

Alaska - State of Alaska International Airports System - Revenue Refunding Bonds - Series 2021A/B/C

CUISP #011842
8/12/2021
$85,515,000
Moody's "A1" (with a Positive Outlook assigned)
Fitch "A1" (with a Stable Outlook assigned)
State of Alaska (msrb.org)

The Official Statement discussed the following issues to impact the Airport facilities: COVID-19 Risks, oil prices and associated volatility, cost and availability of Aviation Fuel, and climate change and possible new regulations implemented at the federal, state, and local levels that would affect operations. Potential EPA (Environmental Protection Agency) regulations could be as stringent as the approved International Civil Aviation Organization standards adopted March 6, 2017. When these regulations would be implemented is unknown. Climate change mitigation measures to assure resiliency are not specifically discussed; however, force majeure events are risk factors mentioned with no mention of plans to prepare in advance.

New York - Transportation Development Corporation - Special Facilities Bonds – LaGuardia Terminal B Redevelopment Project - Series 2016A/B

CUISP #650116
5/17/2016
$2,410,380,000
Fitch "BBB(EXP)"
Moody's "A2"
S&P "AA"
New York Transportation Development Corporation

The non-taxable, non-recourse special facilities, Series 2016A-B bonds described in this document pertain to redevelopment of Terminal B and adjacent pavement, structures, and facilities at LGA airport. The project was undertaken because the pre-existing Terminal B was outdated, inefficient, and undersized for current passenger demand. Passenger demand is forecasted to steadily grow through 2050. The airport's demand resilience is further reinforced by its central location in a large metropolitan area, although the airport has no room to feasibly expand. Given this, higher mean temperatures from climate change could limit aircraft size using the airport. Its waterside location makes it high-risk for flooding from storms (including hurricanes) and sea level rise. Should climate change factors overwhelm the airport, neighboring JFK and EWR airports could not absorb all the passenger demand as they have similar geographic growth constraints, ensuring LGA's long-term resilience as an aviation hub while climate-change adaptation is practiced.

Massachusetts - Massachusetts Port Authority - Revenue Bonds - Series 2021D/E
CUISP #575896
3/10/2021
$405,530,000
Fitch "AA"
Moody's "Aa2"
S&P "AA-"
Massachusetts Port Authority

The non-taxable, non-recourse Series 2021D-E revenue bonds described in this statement are to fund general capital improvements at BOS. It is part of a larger Massport $3.1 billion capital program spanning 2021-2025. The statement includes significant discussion of Massport Resiliency Program and its application to BOS, including flooding hazards due to extreme storms and sea level rise. The Program has a 25–100-year outlook on climate change and its impacts on all existing and projected Massport assets. In the case of BOS, the threats of more frequent and longer-lasting power outages, fuel shortages, and service disruptions resulting from severe weather are acknowledged. Massport has Floodproofing Design Guidelines for new and retrofitting infrastructure to boost physical resilience to inundation. Massport also has Flood Operation plans, drills, and training. It has also developed a web-based geospatial resiliency dashboard and incident reporting application to facilitate planning and response to severe weather incidents. Massport also publishes an annual sustainability and resiliency report. Although physically locked in size, BOS has six long, multidirectional runways, making it adaptable to mean daytime temperature increases and shifts in prevailing winds. BOS is well positioned for demand resilience, being the primary origin-and-destination hub for New England with no comparable alternatives in the region, making airline competition at BOS fierce. Passenger demand is forecast to return to pre-pandemic levels by 2026, however, regardless of passenger demand, BOS benefits from its status as an air cargo hub, which contributes to its operational diversity and demand resilience.

New York - New York Transportation Development Corporation - Special Facilities Revenue Bonds – Delta Air Lines, Inc.: LaGuardia Airport Terminals C&D Redevelopment Project - Series 2018
CUISP #650116
4/24/2018
$1,383,495,000
Fitch "BBB-"
Moody's "Baa3"
https://emma.msrb.org/ES1146688-ES897107-ES1298352.pdf

The non-taxable, non-recourse special facilities bonds described in this document pertain to the redevelopment of Terminals C and D at LGA. Proceeds from the series 2018 bonds are loaned to Delta Air Lines, Inc., which operates a hub in LGA Terminals C and D, and is managing construction of their redevelopment. This project constitutes the reconstruction of: LGA's Terminals C and D and contiguous aircraft aprons, contiguous frontage roads to these terminals, and temporary passenger facilities to continue operations during construction. Also included in the project is a new pedestrian connection to and expansion of the East Parking Garage, and unifying architectural connections to LGA's new Central Hall and Terminal B. The project was undertaken because LGA's pre-existing Terminals C and D were outdated and inefficient based on ca. 2018 passenger and industry standards, were past their useful lives, and were undersized for (ca. 2018) current and projected passenger demand. Additionally, with the redevelopment of Terminal B at the airport, a more streamlined appearance was desired.

The physical and economic resilience of LGA Airport is discussed in a previous subsection of this report assessing the official bond issuance statement from the New York Transportation Development Corporation for the Terminal B reconstruction project. This official bond issuance statement for Terminals C and D redevelopment makes only general, passing mention of potential climate change effects on the project and on LGA. Where this is mentioned, it is regarding adverse business impacts on airlines and atmospheric turbulence. There is no mention of the new terminal structure's physical resilience against potential climate change effects. While the project is supposedly subject to PANYNJ's 2015 Climate Change Resilience Guidelines, no mention is made of this either.

Hawaii - State of Hawaii - Airports System Revenue Bonds - Series 2022A/B

CUISP #419794
1/20/2022
$262,315,000
Moody's Investors Service "A1", stable outlook
S&P "A+", positive outlook
Fitch Inc. "A+", stable outlook
State of Hawaii (msrb.org)

This statement identifies sea level rise, extreme temperatures and extreme weather events resulting from increasing global temperatures attributable to atmospheric pollution. The Airports systems are vulnerable due to its locations in low-lying coastal areas. Significant investments have been made and continue to be made to address these vulnerabilities. Climate change impacts, and increased passenger awareness could impact demand both locally and globally, infrastructure (Airports System and access) which could in turn impact operations and financial conditions. Federal and state laws and regulations as well as international laws addressing greenhouse gas (GHG) emissions could require additional impacts such as aircraft upgrades, increased cost to fuel, and increasing cost of and potentially reducing air travel demand. Prediction of what and how great the impacts of climate change are unknown. Several agencies have enacted or are enacting legislation to educate the public and take proactive steps to curb the effects of GHG. The statement ends with the understanding that the unknown unknowns could impact the infrastructure but when and to what extent is not clear.

Appendix L: Official Statement Analysis for Toll Roads

Virginia - Virginia Small Business Financing Authority Senior Lien Revenue Bonds (Elizabeth River Crossing OPCO, LLC Project) – Series 2022

CUSIP #928104
Date 1/25/2022
Amount $732,820,000
Moody's "A1"
Fitch "A+"
Virginia Small Business Financing Authority (msrb.org)

This official statement indicates the assets serve as a critical artery for commuters, freight, businesses, and the public sector and serve a large portion of all vehicular traffic traveling throughout the Hampton Roads region. The assets also provide links to the Pot of Virginia and to the Naval Station in Norfolk and are key hurricane evacuation routes for the area. The official statement indicates no significant damage from extreme weather event(s) such as Category 3-5 hurricane is found on the infrastructure. The existing midtown tunnel was sustained during Hurricane Isabel.

New York - Buffalo and Fort Erie Public Bridge Authority Toll Bridges System Revenue Bonds – Series 2017

CUSIP 119427
Date: 6/8/2017
Amount $70,800,000
Fitch "A"
Buffalo and Fort Erie Public Bridge Authority (msrb.org)

This official statement points out a natural disaster, severe weather that damages the Peace Bridge could reduce projected toll revenues or significantly increase the expense of maintaining or restoring the bridge.

Florida – Department of Transportation – Turnpike Revenue Bonds – Series 2009A/B

CUSIP 343136
Date: 07/01/2020
Amount $323,445,000
Fitch Ratings "AA-"
Moody's Investors Service "Aa2"
Standard & Poor's Rating Services "AA-"
State of Florida DOT Turnpike Revenue Bonds

The Florida Turnpike Enterprise, founded in 1953, is the agency responsible for overseeing financing, construction, and operations of a system of tolled roads in the state of Florida (mostly southern Florida). Specifically, the 2009A and B package funding targets highway widening, construction of new express lanes, and improvements to toll facilities and interchanges. There is no mention of long-term climate change mitigation strategies in this official statement, even though Florida is one of the most vulnerable US states to climate change events – particularly more intense tropical storms and flooding. The travel forecast "does not account for any revenue loss resulting from unforeseen events such as future hurricanes or wildfires," but does mention a plan for suspending tolls during extreme weather events.

California - Foothill/Eastern Transportation Corridor Agency – Toll Road Revenue Bonds – Series 2021 A/B/C/D

CUSIP 345105
Date: 01/26/2021
Amount $759,772,000
Fitch Ratings "BBB"
Moody's Investor's Service "Baa2"
Standard & Poor's Rating Services "A-"
Foothill/Eastern Transportation Corridor Agency

The Foothill/Eastern Transportation Corridor Agencies were founded in 1986 to oversee financing, construction, and operations of a system of tolled roads in Orange County, Southern California. Upon founding, the agency had "authority to construct toll facilities and to issue non-recourse bonds backed by future toll revenues and development impact fees." The agency maintains portions of State Routes CA 133 (8 miles, 6 lanes), CA 241 (24.5 miles, 4-6 lanes), and CA 261 (6 miles, 5 lanes). The report outlines several climate-related risks including high winds, floods, landslides, and most notably wildfires, as well as several other risk factors (pandemics, terrorism, earthquakes, etc.). The report additionally outlines potential for wildfires to cause interruptions to operations and the resulting loss of toll revenue, with the 2020 Silverado Fire as the primary example.

Appendix M: Official Statement Analysis for Seaports

Florida - Broward County, FL - Port Facilities Revenues Bonds – 2019A/C

CUISP #11506
09/26/2019
$141,765,000
Moody's "A1" (stable outlook) (senior series)
S&P "A" (stable outlook) (senior series)
Broward County (msrb.org)

The Port facilities and the local infrastructure that provides essential services to the facility could be impacted by the events of extreme weather, and natural disasters (flood, droughts, and hurricanes) in the short and long term. As a result, the port could face a lot of negative economic impacts like a loss in property value, a decline in net revenues and an increase in recovery costs. To tackle this risk, the county has implemented the Florida regional climate action plan and developed tools to identify risks, updated design standards, and inform policy solutions. There is no assurance that future extreme weather events will occur and that they would damage the port facilities.

Florida - Canaveral Port Authority, FL – Port Improvement Revenue Bonds – Series 2018A/B

CUISP #137288
12/21/18
Moody's: "A2"
Fitch: "A"
Canaveral Port Authority (msrb.org)

The Port District Marine Facilities could be negatively affected and damaged by extreme weather, sea level rise and natural disasters including floods, hurricanes, tidal surges, droughts, and similar storms. The economic impacts resulting if these events occur will be loss in property value, decline in gross revenues and escalated recovery costs. The authorities have adopted the hurricane plan protective measures to be affected in the port district and to make port marine facilities safer in case of a hurricane strike. Although the Port District has insurance that covers buildings and structures located on the land, there is no assurance that proceeds of the insurance would be sufficient to compensate the total cost incurred from storm damages such buildings.

Guam - Port of Authority of Guam – Port Revenue Bonds – Series 2018A/B/C

CUISP #400652
07/11/2018
$71,445,000
Moody's Investors Services, Inc. "Baa2"
S&P Global Ratings "A"
Port Authority of Guam (msrb.org)

The Port Authority is unable to predict if they will be affected by climate change while the 2018 bonds are outstanding. However, they recognized that any such events will negatively impact the operations and the revenues of the Port Authority. In addition, they have no guarantee that their insurance will cover all the costs in case of any issue related to climate change because, it will depend on the insurance coverage and limit they carry at that time if any negative climate events happen in the future.

Florida - Hillsborough County Port District, FL – Revenue Bonds (Tampa Port Authority Project) - Series 2018A/B

CUISP
9/19/2018
$46,255,000
Fitch Ratings, Inc "A" (stable outlook)
Hillsborough County Port District (msrb.org)

The Port could be impacted by extreme weathers, sea level rise and natural disasters including flood, hurricane, and droughts, which could result in the damage of the port facilities and the local infrastructures that provides essential services to the port. The occurrence of such events will negatively impact the gross revenues of the port and create a loss in their property value. The port decided to adopt the hurricane plan as a protective measure against any negative impacts that these events will cause on their facilities and operations. Also, they predict a negative shift in demand if impacted by climate events, because cargo will be redirected to other operational ports in the area.

Texas - Port of Houston Authority of Harris County, TX - First Lien Revenue Bonds - Series 2021

CUISP #734262
11/15/21
$315,950,000
Moody's: "Aa3"
S&P: "AA+"
Port of Houston Authority of Harris County (msrb.org)

The Port operations are vulnerable to the effects of sea level rise, extreme climate conditions and the authorities recognize the urgency to allocate more financial resources to address these vulnerabilities. The Authorities expect to continue their operations and construction activities to minimize the future effects of these occurrences. Additionally, they also believe they can adapt to these disruptions. However, the authorities give no guarantee that the effects of sea level rise will not adversely affect their revenues.

California - Port of Oakland, CA - Intermediate Lien Refunding Revenue Bonds - 2021 Series H (AMT) (Forward Delivery)

CUISP #735000
02/02/21
$182,010,000
S&P "A"
Moody's "A2"
Fitch "A"
Port of Oakland (msrb.org)

The Port operations and infrastructure are vulnerable to the effect of sea level rise, extreme climate conditions, and extreme weather and significant capital investment will be necessary to address these vulnerabilities. In the long term, these events may reduce demand for cargo shipment locally and globally, and negatively impact the port's financial condition. An assessment by the California Energy Commission shows that portions of the port area may be subject to sea level rise-related inundation. However, the port is unable to predict if the impacts of such events will happen while the bonds are outstanding. Climate change related events will have an adverse impact on the port's facilities, their revenues, and expenses.

Washington - Port of Pasco, WA - Limited tax General Obligation Refunding Bonds, Series 2020

CUISP #735150
09/01/2020
Port of Pasco, Washington
$3,630,000
S&P Global Ratings: "A"
Port of Pasco, WA (msrb.org)

The Port is susceptible to the events of extreme weather, sea level rise along the coast, and flood, and can give no assurance that the insurance carried by the Port will be enough to cover the damage of the port facilities in case such events occur. The port, the local community and their economy will be negatively impacted in case of any negative climate related events.

Washington - Port of Tacoma, WA - Revenue Refunding Bonds – Series 2019

CUISP #735439
09/30/2019
$34,630,000
Moody's: "Aa3"
Standard & Poor's: "AA-"
Port of Tacoma (msrb.org)

The Port facilities and other license properties are exposed to climate change and the Port can give no assurance that the insurance they carry will be sufficient to rebuild and reopen their facilities in case of any climate related events. The Port does not expect that their facilities will experience any major vulnerability during the period of their design life.

Florida - Manatee County Port Authority, FL - Taxable Revenue Refunding Bonds - Series 2021

CUISP #561850
04/14/21
$35,055,000
Manatee County Port Authority (msrb.org)

The operations of the Port could be delayed or stopped by damaging storms, wind, and flood. As a result of these events, the Port could experience a potential loss of business, an increase in expense and the inability to provide services due to the material damage to the Authority's equipment. In addition, there is no assurance that the Port's insurance could cover all the damage incurred by these events. The Port Authority has developed a heavy weather plan and partnered with the Tampa Bay Regional Council to make the Port facilities and structures more resilient to climate related events.

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