September 2019

Assessment of Planning Risks and Alternative Futures for the Florida Transportation Plan Update
Project BDV31-977-98

Planning Implications for Alternative Futures

Final Report

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Assessment of Planning Risks and Alternative Futures for the Florida Transportation Plan Update		5. Report Date September 2019
		6. Performing Organization Code 55220000977
7. Author(s) Ruth L. Steiner, Jesse Anderson, Nathaniel Chan, Abhinav Alakshendra, Richard Doty, Crystal Goodison		8. Performing Organization Report No.
9. Performing Organization Name and Address University of Florida P.O. Box 115701 Gainesville, FL 32611-5701		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. BDV31-977-98
12. Sponsoring Agency Name and Address Florida Department of Transportation (FDOT) 605 Suwannee Street Tallahassee, Florida 32399-0450		13. Type of Report and Period Covered
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A strong consensus is emerging that changes in technology, environmental conditions, demographics and associated travel choices, global trade and security, and transportation funding increase risks in long-range transportation planning. These factors are creating a need to develop a diverse set of alternative future scenarios that address these risks and their timing. This report summarizes the research that is presented in four previous technical memoranda that document the risks associated with these risk categories as a part of the update of the Florida Transportation Plan (FTP). In this report, we first define the terms associated with risk assessment, in particular, vulnerability, target/asset, threat, likelihood, consequences, and risk. We then summarize the risks associated with these uncertainties, vulnerabilities, assets affected, the level of vulnerability and the consequences associated with these five broad sources of transportation risk: population, demographics, and migration; economics and revenues; environment; technology; and global issues including security. We then explore the uncertainty leading to risk and the consequences for each of the five risks associated with the FTP: Return to Historic Growth, Rural Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon. We develop a risk matrix for each of the five broad categories of risk that summarizes the likelihood, frequency, vulnerability, thresholds and consequences of risks. We end the document with examples of best practices from other U.S. states and recommendations for the FDOT to incorporate into the update of the FTP.

17. Key Word	18. Distribution Statement
Risk, Vulnerability, Transportation Planning, Transportation Risk, Urban Planning	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		175	

ACKNOWLEDGMENTS

The research team would like to thank Jennifer Carver of the Florida Department of Transportation (FDOT) Policy Planning Office for her assistance and patience in understanding the scope of this project and for providing feedback on the document. We would also like to thank her, Dana Reiding, and Jim Halley of the FDOT Policy Planning Office for their work in organizing the Long-Range Visioning Session and providing a positive experience for the students of the University of Florida Department of Urban and Regional Planning Transportation Planning Risk Studio. We would also like to thank the students who participated in the Transportation Planning Risk Studio for their contributions to our thinking about these topics and their summaries of best practices.

EXECUTIVE SUMMARY

A strong consensus is emerging that changes in technology, environmental conditions, demographics and associated travel choices, global trade and security, and transportation funding increase risks. These factors are creating a need to develop a diverse set of alternative future scenarios that address these risks and their timing. This report summarizes the research that is presented in four previous technical memoranda that document the risks associated with these risk categories as a part of the update of the Florida Transportation Plan (FTP). In this report, we first define the terms associated with risk assessment, in particular vulnerability, target/asset, threat, likelihood, consequences, and risk. We also define the policy goals that have been used in previous versions of the FTP and the five scenarios – Return to Historic Growth, Rural Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon – developed in the most recent FTP. We then summarize the risks associated with these uncertainties, vulnerabilities, assets affected, the level of vulnerability and the consequences associated with these five broad sources of transportation risk: population, demographics, and migration; economics and revenues; environment; technology; and global issues including security. We then explore the uncertainty leading to risk and the consequences for each of the five risks associated with the FTP: Return to Historic Growth, Rural Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon. We develop a risk matrix for each of the five broad categories of risk that summarizes the likelihood, frequency, vulnerability, thresholds and consequences of risks associated with each of the general categories of risk. We end

the document with examples of best practices from other U.S. states and recommendations for the FDOT to incorporate into the update of the FTP.

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AV	Autonomous vehicles
B2C	Business to consumer
BEBR	Bureau of Economic and Business Research
CAPTA	Costing Asset Protection: An All-Hazards Guide for Transportation Agencies
CAV	Fully connected and autonomous vehicles
CPRA	Coastal Protection and Restoration Authority (in Louisiana)
CRS	Community Rating System
CV	Connected vehicles
DDOT	District of Columbia Department of Transportation
EV	Electric Vehicle
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FTP	Florida Transportation Plan
GHG	Greenhouse gas
IRVA	Integrated Regional Vulnerability Assessment
LRTP	Long-range Transportation Plan
NCSL	National Conference of State Legislatures
PPP	Public-private partnership
SAVs	Shared-autonomous vehicles
SoFlo	South Florida
TNC	Transportation network company
TxDOT	Texas Department of Transportation
TSA	Transportation Security Administration
USDHS	United States Department of Homeland Security
USEPA	United States Environmental Protection Agency
V2V	Vehicle to vehicle
V2I	Vehicle to infrastructure
VMT	Vehicle miles traveled

Planning Implications for Alternative Futures

Introduction

A strong consensus has emerged that changes in technology, global issues including security, environmental conditions such as sea level rise and extreme weather events, the unique needs and preferences of changing demographics, and changes in economics and transportation revenues increase transportation planning risks. These factors are driving the need to develop a diverse set of alternative future scenarios that address these risks and the timing of their associated changes. The Florida Transportation Plan (FTP) is the single overarching statewide plan guiding Florida's transportation future. It is a plan for all of Florida, created by, and providing direction to, the Florida Department of Transportation (FDOT) and all organizations that are involved in planning and managing Florida's transportation system, including statewide, regional, and local partners in the private, public, and non-profit sectors. The FTP fulfills the requirements established in Chapter 339.115, Florida Statutes.

Purpose of This Report

This report builds on a year-long research project presented in four technical memoranda, and presents the culmination of the associated findings. The first assessed the planning risks resulting from changes in population, demographics, and migration; economics and revenues; environment; technology; and global issues, including security. The second documented the consequences of uncertainty, the level of vulnerability, and overall risk. The third identified the planning implications for alternative futures, and the fourth identified how risks can be addressed in the project-level transportation planning processes. Throughout this research process, we have based our approach on a diagrammatic representation of risk from the *Costing Asset*

Protection: An All-Hazards Guide for Transportation Agencies (CAPTA) NCHRP Report 525 (SAIC & PB Consult, 2009) that develops a consequences-based methodology to "analyze assets, relevant threats and hazards, and consequence levels" (p. 1). Their framework considers risk as a function of likelihood – the existence of a hazard or threat plus vulnerability – and the consequences of an adverse event on an asset and the affected population (SAIC & PB Consult, 2009). For convenience, we include the diagram from that report, below, to show the connection between targeted assets, vulnerability, threats and consequences (Figure 1).

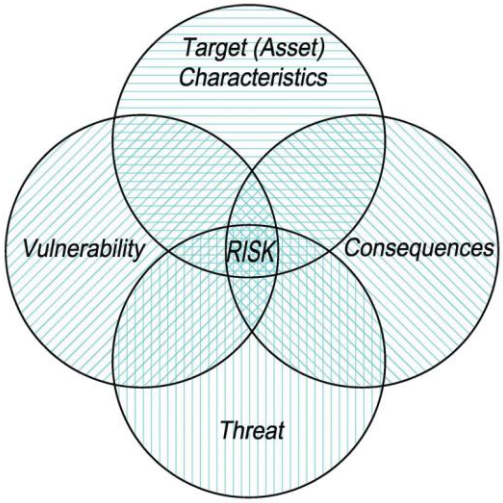

Figure 1: The Contributors to Risk (Source: SAIC & PB Consult, 2009)

Risk is inherently complex and subjective. The complexity of transportation risks is depicted throughout this document and is summarized with a web of transportation risks. This web of transportation risks not only denotes the complexity of identifying risks, it also represents the ever-increasing complexity of the synergistic characteristics interrelating each types of risk. For example, automation of vehicle operations is a technological risk that synergistically impacts the economy through employment and the population through further diversifying transportation choice and impacting road safety.

These interconnections can be present in various forms and, as such, the web of risks is far from comprehensive, rather it depicts the most pertinent risks and interrelations identified throughout the planning process.

Definitions

Throughout this project, the target/asset has been defined as “persons, facilities, activities or physical systems that have value to the owner or society as a whole” (SAIC & PB Consult, 2009: 1). The threat or hazard can be seen as the potential event, or intentional or unintentional act, capable of disrupting or affecting an asset (SAIC & PB Consult, 2009: 9). Within the context of this project, we refer to the threat or hazard as an “area of concern” with the associated potential uncertainties. Vulnerability is defined as “[a] weakness in asset design or operations that is exposed to a hazard or can be exploited by a threat resulting in negative consequences” (SAIC & PB Consult, 2009: 9). Furthermore, risk is defined as the “effect of uncertainty on objectives” (ISO, 2018). In this context, ISO notes that “an effect is a deviation from the expected” with the potential to be “positive, negative or both, and can address, create or result in opportunities and threats”, whereas an objective “can have different aspects and categories, and can be applied at different levels” (ISO, 2018). Using this definition of risk enables planners to think creatively about characteristics related to the transportation network in a synergistic manner, rather than limited to traditional static approaches to risk identification.

Throughout this research process, risk has been textually characterized by vulnerabilities, threats, consequences, and targeted assets. Through this method of understanding risk, we were able to better reveal the synergistic nature of the various

risks first identified through the participatory process discussed below. By doing so, secondary, indirect, and cumulative impacts were further uncovered, leading to the web of risks that is described this document. While this process has led to the fruitful production of planning matrices and tables to further inform statewide transportation planners, this final report summarizes and expands upon the notion of risk.

Specifically, this report extends the characterization of risks through qualifying them with levels of likelihood, frequency, vulnerability, and consequences and identifying whether there is a tipping point, or threshold, associated with each given risk This expanded method of qualifying the components of risk fulfills the recommendation set forth by the NCHRP Report 525, which communicates risk as “the quantitative or qualitative expression of possible loss that considers both the probability that a hazard or threat will cause harm and the consequences of that event” (SAIC & PB Consult, 2009, p.10). Furthermore, it qualifies risk as “a function of likelihood (hazard or threat plus vulnerability) and consequences of an adverse event affecting an asset and related stakeholders” (SAIC & PB Consult, 2009, p.10). Thus, the threat or hazard is qualified in terms of the relative dimensions of likelihood, frequency, and vulnerability for the given threat or hazard, as well as its associated level of consequence (SAIC & PB Consult, 2009). “While CAPTA does require the user to determine which assets and which threats and hazards are of greatest concern, the primary judgment required from the CAPTA user is the point (or “threshold”) at which adverse consequences would merit allocation of additional resources to avoid or mitigate the effects of the consequential event” (p.1). However, “[t]he consequence threshold may vary from jurisdiction to jurisdiction and among individual managers, depending on individual tolerance” (p.8).

As such, the research process has identified sources of risk with potential thresholds or tipping points to further convey the extent of the associated consequences without predefining said thresholds.

In addition to identifying the impact, level of vulnerability and consequences of each uncertainty, this report discusses synergistic risks. More specifically, we examine the interactions between the five broad sources of risk, and their associated areas of concern in transportation planning. A multitude of interrelations across the different categories of risk compounds them. For example, because petroleum-based fuels dominate the transportation sector, changes in transportation fuels are likely to have major impacts on the design of the transportation system and the vehicles used on it, and the associated air and water pollution, and greenhouse gas (GHG) emissions. At the same time, other changes in technology and telecommunications are increasing transportation choice for all users of the transportation system. For example, persons who do not drive because of their age (too old or too young) or physical and cognitive abilities, will have a greater variety of options about how and when they travel. The availability of electric vehicles (EVs) operated by a driver or in autonomous mode will facilitate that choice. At the same time, the options may be costly or only available to people who live in the service territory of the provider. The following discussion attempts to bring attention to how the identified uncertainties combined with their varying levels of vulnerability and resulting consequences lead to risk while further acknowledging and assessing the diverse sets of impacts and interactions that synergistically occur among the five sources of risk.

In this report, we summarize direct, indirect and cumulative effects as they relate to the policy goals of the FTP. The National Environmental Policy Act (NEPA) guidance defines three types of effects: direct, indirect, and cumulative. Direct effects "are caused by a direct result of an action and occur at the same time and place" (AASHTO, 2016: 1), whereas indirect effects "are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable" (AASHTO, 2016: 1). Finally, cumulative impacts are defined as an "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (AASHTO, 2016: 2).

In this report, these impact definitions are applied to the 2060 FTP goal areas of safety and security; efficient and reliable mobility; economic competitiveness; environment and energy conservation; agile, resilient and quality infrastructure; transportation choice; and quality places (FDOT, 2015a; FDOT, 2015b).

The current or earlier versions of the FTP describe or define each of these policy goals (FDOT, 2010; FDOT, 2015a; FDOT, 2015b). The first four goals – safety and security; agile, resilient, and quality infrastructure; efficient and reliable mobility; and transportation choices – relate to transportation system performance, while the remaining three – economic competitiveness, quality places, and environment and energy conservation – provide transportation support for statewide priorities. The current FTP does not define safety and security. However, security is the defined in a 2010 FTP document as "actions taken to protect system users and workers, critical infrastructure, cargo and other assets, and communities from terrorism and crime

related to the transportation system" (p.28). Safety is defined as "relative freedom from danger, risk, or threat of harm, injury, or loss to personnel and/or property, whether caused deliberately or by accident" (WebFinance, Inc., n. d.). The FTP does not directly define the goal area, agile, resilient, and quality infrastructure. However, agile is defined as "the ability to move or adapt quickly" (p. 39) and resilience is defined as "the ability of the transportation system to absorb the consequences of disruptions, to reduce the impacts of disruptions and maintain mobility" (p. 39). Quality is defined as "degree of excellence" and "superiority in kind" (Merriam-Webster, n. d.). As used in this document, we define "agile, resilient, and quality transportation infrastructure" as "superior transportation system that have the ability to adapt quickly to absorb the consequences of disruptions, or reduce the impact of disruptions and maintain mobility" (FDOT 2015a: 16). Throughout the document, we use the term "quality infrastructure" for this system goal. "Efficient and reliable mobility" can be defined as "the movement of people and goods without unnecessary delay on all modes with reliable travel times" (FDOT 2015a: 16); at times throughout the document, the goal will be described as "mobility". Transportation choice is defined as "the freedom to choose among and move seamlessly through different modes of travel from the start to the end of a trip" (FDOT 2015a: 17). Economic competitiveness is "a state or region's ability to compete in global markets, as evidenced in the attraction of new businesses and the expansion of existing businesses" (FDOT 2015b: 38). Quality places are defined as "vibrant places" that "support community and regional visions, meet the needs of diverse groups of residents, improve accessibility, and expand options for residents and visitors" (FDOT 2015a: 17). The goal to support Florida's environment and conserve energy is called

“environmental stewardship” throughout the rest of the document. Environmental stewardship is defined as the act of “protecting and responsibly managing all of our resources for present and future ecological and human uses” (FDOT 2010) and “a philosophical concept of government, the public, resource users and businesses all taking responsibility and working together to conserve natural resources” (FDOT 2015b: 38).

The FTP Vision Element outlines various scenarios for the future of the state of Florida, and the impact of these scenarios on Florida’s transportation system. These five scenarios consider how changes in population, economy, technology, and the environment affect the transportation system. The four non-risk based scenarios are 1) Return to Historic Growth, 2) Rural Rediscovery, 3) Global Trade Hub, and 4) Innovation Hub. The last scenario, Risks on the Horizon, encompasses all risks related to Florida’s transportation system. The FTP Vision Element states that it is likely that a combination of each of the scenarios is likely to occur, rather than a single scenario. These scenarios can help inform future decisions regarding the risks to Florida’s transportation system, and how to best address them. This research seeks to inform the FDOT about how these risks interact with the existing planning scenarios: Return to Historic Growth, Rural Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon (FDOT, 2015a).

The potential futures, or scenarios, reflect a range of possibilities facing Florida’s transportation system and not a single preferred future. The future path may reflect elements of each of the five scenarios; the scenarios have some overlap between them. The Return to Historic Growth assumes high growth in population and the economy with

similar development patterns and industry mix as today (FDOT, 2015a). The Rural Rediscovery scenario focuses on rural areas and smaller towns and includes new industries and traditional industries, such as agriculture and eco-tourism (FDOT, 2015a). The Global Trade Hub includes “significant expansion in global trade, tourism and investment” (FDOT, 2015a: 9). The Innovation Hub “emphasizes technology and innovation, particularly in urban centers” (FDOT, 2015a: 9). The Risks on the Horizon scenario include a diverse set of risks including “slowing population growth, economic uncertainties, or extreme weather events and climate trends” (FDOT 2015a: 9).

Research Process and Organization of the Document

This document is organized into sections for each of the five broad sources of risk in transportation planning: population, demographics and migration; economics and revenues, environment, technology; and global issues, including security. In each section, we summarize the findings from the previous technical memoranda, identify examples of best practices and make recommendations about how account for risks in the transportation planning process.

This research was conducted through a variety of methods to understand the complexity of risks. These included the use of the expertise of members of the project team in the five areas of risk, a set of webinars with representatives from the private, public and non-profit sectors and a transportation planning studio involving five students. These processes were designed to bring out a variety of perspectives that could provide a diversity of perspectives about risk in transportation planning.

The research team was comprised of subject experts in the five areas of risk described in this research. Richard Doty is a research demographer for the University of Florida Bureau of Business and Economic Research (BEBR). He assisted in the

development of our understanding of risks associated with population, demographics, and migration. Abhinav Alakshendra is an assistant professor in the Department of Urban and Regional planning, who conducted research in the economic aspects of planning. He helped the research team to understand the risks associated with economics and revenues, and global issues including security. Crystal Goodison, who is the Associate Director of the GeoPlan Center and an Associate Scholar has significant expertise on the impacts of climate change on the transportation system and the use of geographic information systems data to support transportation analysis. She worked with research assistants, Adam Carr, to understand the environmental risks in the transportation system. Nathaniel Chan, who also participated in the transportation risks studio, joined the research team in November 2018 and provided expertise on environmental risks. Ruth Steiner and Jesse Anderson worked on all areas of risk and put together the technical memoranda prepared throughout this project. The research team occasionally consulted with Maria Cahill, who is currently a planner for Orange County and former State Growth Management Coordinator for the FDOT, about details related to the transportation planning process in Florida and other details about specific programs.

The webinar meetings took place during the week of June 10, 2018, with four groups of participants, most of whom have previously been involved in the development of the FTP or who are interested in transportation planning in Florida. As shown in Table 1, the groups included: private sector organizations, non-profit organizations, public sector – regional organizations, public sector – FDOT, and public sector – local organizations. A fifth group meeting was organized with participants in the public sector

at the federal and statewide level. Although two participants indicated they would attend the meeting, no participants joined the webinar. The results of these webinars were recorded and members of the team took notes during the meetings. Throughout this report, the comments from these meetings are identified not by the individual but by the number of the meeting in which an aspect of risk was identified and discussed.

Table 1. Stakeholder Interviews (Meeting Type and Attendees)	
Meeting 1: Private Sector 6/12/18 10:00-11:00am	
Ananth Prasad	Florida Transportation Builders Association
Ken Armstrong	Florida Trucking Association
Bob Ward	Council of 100
Bob O'Malley	CSX
Chris Emmanuel	Florida Chamber of Commerce
Casey Grigsby	Florida Ports Council
Karen Deigle	Florida Public Transportation Association
Steven Bimholz	Council of 100
Meeting 2: Nonprofit	
Thomas Hawkins*	1000 Friends of Florida
Janet Bowman*	The Nature Conservancy
Meeting 3: Public Sector (Regional and Local)	
Eric Poole	Florida Association of Counties
Lois Bush	FDOT District 4
Whit Blanton	Forward Pinellas
Pat Steed	Florida Regional Councils Association
Larry Hymowitz	FDOT District 4
Denise Imbler	Florida Regional Councils Association
Meeting 4: Public Sector (Federal and Statewide)	
No Attendees	
Meeting 5: FDOT Staff and Consultant Staff	
Jim Wood	FDOT
Regina Colson	FDOT
Chris Wiglesworth	FDOT
Brian Watts	FDOT
Frank Collins	FDOT
Lora Hollingsworth	FDOT
Tom Byron	FDOT
Melanie Weaver Carr	FDOT
Jennifer Carver	FDOT
Dana Reiding	FDOT
* - At the request of participants, these interviews were conducted individually.	

Finally, a group of five students participated in this research and gathered a variety of information in an Urban Planning Project course (URP6341), taught by Ruth Steiner and Paul Zwick, that took place during the fall of 2018. In that course, students independently identified the sources of risk, completed analysis on one of the five categories of risk, developed three potential scenarios to evaluate risk, identified best practices in state and local governments addressing these risk in transportation planning and developed a specific scenario for which they provided detailed analysis. As such, the students identified the areas of concern associated with each risk independent of the research team. For the best practices, Federal Highway Administration (FHWA)/Federal Transit Administration (FTA) State Long Range Transportation (LRTP) Database (USDOT, n. d.) formed the core of their exploration.

Thus, members of the research team and the students – Nathaniel Chan, Austen Dole, Andrew Morris, Aastha Patel and Rosemary Fusco – assisted in the research team's thinking about risk based upon their areas of expertise. Austen Dole explored issues related to planning for population, demographics and migration, with a focus on aging, Aastha Patel in risks associated with the economy and revenues and critical facilities, Nathaniel Chan in risks associated with the environment, Andrew Morris with technology risk, with a focus on freight movement, and Rosemary Fusco in risks associated with Global Issues and the impact on land and property. Each of these students also prepared a final project and an associated white paper that described the risks associated, in most cases, with the interaction between their area of risk and the overall risk associate with sea level rise. Throughout the semester, the members of the research team participated actively in the course. Each member of the research team

made a presentation early in the semester about their understanding of risks in their area of expertise. They also participated in reviews of the student work in an informal setting throughout the semester and in more formal presentations during the middle and end of the semester.

In this final report, we summarize the risks identified throughout the research and their associated uncertainty, vulnerabilities, assets affected for five major areas of risk: population, demographics, and migration; economics and revenue, environmental, technology, and global issues including security. We then summarize the nature of the impacts and the extent to which the impacts – direct, indirect, or cumulative – interact with the goals of the most recent FTP – safety and security; agile, resilient and quality infrastructure; efficient and reliable mobility; transportation choices; economic competitiveness; quality places; and environment and energy conservation - and the time frame for vulnerability. We then assess the interactions between the five broad categories of risk and the five FTP scenarios - Return to Historic Growth, Rural Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon. We then develop a risk matrix to summarize the likelihood, frequency, vulnerability, threshold and consequences of each of the five categories of risk, the key to which is provided in Table 2 below. Once we have reviewed the five general categories of risk, we discuss their synergies through the development of a web of risks. Next we review the best practices in addressing the five broad categories of risk and then make recommendations about how the FDOT can incorporate risk into its planning processes.

Table 2. Risk Matrix Key				
Likelihood	Frequency	Vulnerability	Threshold	Consequences
Expected	Ongoing	High	Yes	Extreme
Likely	Near future	Moderate	No	Moderate
Probable	Long term	Low		Minor
Unlikely				

Population, Demographics, and Migration

Risks

The risks associated with transportation planning result from an increase in the overall population, changes in the demographic composition of the population, including more non-English speakers, the aging of the population, and the movement of Millennials into their prime earning and childbearing years. A significant risk in planning for changing demographics is the potential for a misallocation of funds due to transportation investments not matching population projections or actual trends, and the potential for increased pressure on existing infrastructure if trends and predictions come to fruition. Additional risks include the need for more diverse and accessible modes of transportation for a growing number of non-drivers - older adults, Millennials who choose to live in urban centers without automobiles, those who cannot afford to own and maintain a vehicle, and populations who can't drive due to cognitive or physical limitations.

Related risks include increasing pressure for efficient and effective evacuation procedures for non-driving adults and their dependents, and the risk of older adults becoming stranded in place. Additionally, equitable accessibility to transit options and the potential of mismatch between transit options and economic opportunities are other potential risks. Similarly, changes in statewide demographics cause risks through

changes in vehicle ownership rates, mode preferences, and the associated changes in transportation-related revenues. Lastly, Florida's population and its tourist composition are becoming even more diverse, causing more language barriers to originate across the transportation system and hindering the mobility of the state's residents and its tourists.

The risks originating from population change are largely location specific due to the spatial concentration of current and future populations. As the population continues to grow, the state must proactively plan for the impact on the physical infrastructure of roadways, safety, and the need for the increased capacity for all modes. These new or growing concentrations of the population will require new or expanded transportation infrastructure and services, such as additional corridors or additional multimodal options in existing corridors. If population projections hold true, increasing populations will increase the vehicle miles traveled (VMT) and cause additional wear and deterioration of our transportation infrastructure (Table 3).

This may lead to a risk in poor driving conditions on our roadway network and require development of multimodal options and parallel corridors to reduce congestion, added wear and tear, and overall deterioration. However, there is also risk and uncertainty if population projections do not meet projected figures or if the projected growth patterns differ from actual patterns. If FDOT continues to plan and invest in physical infrastructure improvements, risk may come in the mismatch of funding for projects to support the increased population and the location of growth.

Older adults bring uncertainty in preferences, location and mobility options throughout the state. As stated in Technical Memoranda 1 and 2, older adults are

vulnerable users of the system. As they age, they slowly but incrementally lose the capacity to drive due to physical and cognitive impairments. This has implications for their travel preferences (by time of day and week, and mode of travel), their accessibility to activities of daily living, and, in extreme cases, their ability to evacuate during a storm event. As FDOT plans for this component of the population, risk in the categories of overall quality of life, aging in place, migration, and evacuation routes must be considered.

Lastly, the changes in the components of the populations – both in age and in the demographic characteristics – lead to future risks for Florida. As is discussed in previous technical memoranda, Millennials may prefer urban environments and shared mobility or non-automobile modes of travel more than Baby Boomers (Norberg, Steiner & Strekalova, 2017). Similarly, newly arriving immigrants may have more experience in using public transit than in driving (Chatman & Klein, 2009). Ensuring that there are equitable transportation options that account for language and other barriers is a risk as diverse new populations are migrating to Florida in large numbers from both foreign and domestic sources. The state of Florida has depended upon continued growth for many years and the transportation needs of the state interact with the rate of population growth, its geographic distribution, and the components of change in population, including the aging of the population, and the change in tastes between generations. As is represented in Table 3, varying levels of uncertainty and vulnerability leads to risks within the broad source of risk of shifting population, migration, and demographic trends.

Table 3. Uncertainties Leading to Risk in the Transportation System Related to Population, Demographics, and Migration						
Area of Concern	**Potential Uncertainty**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of each type of uncertainty**	**Risk**
Population Change	The amount of population change and the spatial distribution of that change	Unplanned demand for new infrastructure and maintenance of existing infrastructure Increased multimodal choices complicate evacuation	All modes of transportation infrastructure, international trade, freight and aviation	Moderate to High in the short term, High in the mid to long term	Greater than expected increase in unplanned increase in congestion, VMT, and maintenance cost. Less than expected growth (or decline) results in misallocation of resources in the wrong places.	Physical impact and deterioration of infrastructure. May lead to more crashes on roadways Misallocation of resources of we invest in infrastructure in the wrong place
Aging Population	Greater proportion of aging residents and where they are located	More aging residents unable or unwilling to drive, or unable to drive safely, or at night Lack of access to mass transit and ride sharing, particularly outside of urban areas Greater proportion of population with evacuation difficult	All modes of transportation infrastructure	High in the short term, High in the Mid to long term	Lack of mobility options for an aging population, particularly outside of urban areas Increasing costs of providing alternative transportation options Greater demand for service sector and health care-related VMTs Public safety issues	Decrease in overall quality of life for older adults due to lack of travel opportunities, especially in rural areas Need for efficient and safe evacuation in times of natural disaster Older adults in rural environments have few affordable and convenient transportation choices
Generational Changes	Behavioral changes due to different generational preferences and tendencies	Increased reliance of Millennials and younger generations on alternative forms of transportation (such as ridesharing, biking, mass transit)	All modes of transportation, especially non-traditional ones Increasing demand for urban transportation options	Moderately High in the short term, Moderately High in the mid to long term	Greater demand in mass transit, bike-friendly infrastructure, rise-sharing programs, and electric changing stations	Fewer individuals own a personal vehicle so funds collected via gas tax or tolls decrease and emergency evacuation is more difficult

Table 3. Uncertainties Leading to Risk in the Transportation System Related to Population, Demographics, and Migration (continued)						
Area of Concern	**Potential Uncertainty**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of each type of uncertainty**	**Risk**
Changes in Components of the Population	Changes in the proportions and origins of migrants, changes in race/ ethnicity, and changes in birth or death rates	Potential reductions in income and lack of access to transportation options Language and cultural barriers	All modes of transportation infrastructure, especially public transit	Moderately High in the short term, Moderately High in the mid to long term	Lack of mobility options and different travel preferences for more diverse population, particularly outside of urban areas	Limited mobility options for vulnerable populations Inability to travel to employment opportunities resulting in less economic opportunity

Interactions with FTP Goals

It is generally accepted that Florida will experience significant population growth for the near future (Rayer & Wang, 2018). Population changes, like that of continuous growth, significantly impact various goals of the FTP, especially when population change is geographical concentrated. Population change directly affects the goals of quality infrastructure, mobility, transportation choice, and economic competitiveness. Increased population, especially to the extent anticipated in Florida, will place added stress on the current infrastructure, leading to further wear and tear. Added use of the infrastructure will necessitate increased maintenance to ensure a functioning transportation system. Moreover, providing resilient infrastructure will be a challenge due to the added transportation infrastructure, causing further delays in repairs and upkeep.

The growth in population would affect all modes of transportation, resulting in increases in traffic and congestion. Consequently, demand for mobility would be constrained without additional infrastructure and facilities to support the growth. Population growth will directly affect economic competitiveness, as a growth in

population will most likely lead to job creation and further development within the state. Population change will directly affect safety and security, as well as quality places. Significant increases in the overall population of Florida would place added pressure on the safety and security measures currently employed by the state. Increased congestion and traffic for all modes of travel would affect the safety and security of the transportation system, with a likelihood of increases in the number of crashes.

Subsequently, the geographical distribution of population growth and its effects on economic competitiveness, mobility, and transportation choice would indirectly affect the FTP goal of quality places. Population change is likely to have cumulative impacts on environmental stewardship, as well. Similar to the impacts on quality places, the pattern of development related to population growth will have adverse impacts on the environment. As such, the consequences of population change focus on the challenges presented by the uncertainty surrounding population growth. Florida can expect changing usage rates for all modes of transportation, with particular emphasis on roadways.

The trends of an aging population directly affect three goal areas of the FTP: mobility, transportation choice, and safety and security (Table 4). If aging continues as is expected, mobility and transportation choice will need to be improved to provide better accessibility for the growing older adult population (Meeting 2). The aging of the population will directly affect safety and security, as a growing number of older-adult drivers, who may have diminished cognitive abilities or physical impairments, may be on the roads and are at greater risk for crashes. As older adults stop driving, they will

require public transit and other transportation services to have greater mobility and transportation choice.

An aging population will indirectly affect the economic competitiveness of the state in two interrelated yet diverging manners. Continuous aging will lead to a growing number of older adults being aged out of the workforce and a shrinking taxpayer to retiree ratio (FEDR, 2014), which will negatively affect economic competitiveness. However, an aging population will result in increasing demand for required services, such as in-home, on-demand healthcare and professional services in the tertiary sector (otherwise known as the more basic of the service sector, e.g., retail) of the economy. In addition, an aging population could also affect the economic competitiveness of the state through apprehensions to and slow adoption of technology (Meeting 3), including transportation technology. The ongoing aging of the population will also indirectly affect the FTP goal of quality places, as the changing demographic structure will alter the needs of the state population. The potential changes in mobility trends associated with an aging population will likely lead to a cumulative need for quality infrastructure, especially if the transportation system were to undergo changes to become more multimodal. Aging of the population will likely cumulatively affect environmental stewardship through adoption rates of advancing transportation technologies and varying generational levels of environmental awareness. Thus, the consequences of an aging population largely center on the mobility of older adults within the state.

Generational changes directly affect the FTP goals of mobility, transportation choice, and quality infrastructure (Table 4). While all generations want efficient, convenient, and reliable mobility, the generations show differences in preferences of

different modes of travel. While the digital divide between older and younger generations is closing, the generations still exhibit a disparity in the rate of adoption of technology (Jiang, 2018). Generational differences regarding the knowledge, acceptance, and adoption of technology could affect the development and deployment of technology-based advancements in transportation infrastructure, equipment, and services. Therefore, until younger and older generations are using technology at a similar rate, the transportation system will undergo transitional periods of incorporating future technologies, along with traditional methods of transportation. Subsequently, the implications from generational changes for quality infrastructure will follow the transitional patterns of mobility and transportation choice.

Generational changes will indirectly affect the FTP goals for environmental stewardship and quality places. As discussed in the aging population section, the indirect impacts of generational changes on environmental stewardship largely stem from environmental awareness, use of technology and energy efficient vehicles, and housing tenure. Similarly, these changes in lifestyle choices and behaviors between generations will indirectly affect quality places.

Generational changes cumulatively affect safety and security, and economic competitiveness. As alluded to above, generational changes will require transitional periods of accounting for both the traditional transportation trends of older generations and the technologically-oriented trends of younger generations. The mixing of a transportation system that employs both traditional and technologically-oriented modes of transportation could have safety implications and require alternative security measures. Generational changes are likely to cumulatively affect economic

competitiveness in the same manner as the aging of the population. Thus, the consequences of generational changes derive from changes in lifestyle preferences and the associated changes in demand for transportation services.

Any changes in the components of the population – by age, race, ethnic origin and migrant status - will directly affect the FTP goals for mobility, transportation choice and quality places (Table 4). As is discussed above, the change in the population by generation is expected to have a separate and independent impact on the demand for transportation services. The changing demand levels for various modes of transportation will affect mobility and transportation choice. Similarly, changes in the components of the population could increase pressure for different lifestyles, affecting community livability. Having various generations and cultures living in the same area will result in differing expectations of what the standard quality of life should be.

Any changes in the components of the population will indirectly affect the FTP goals for safety and security, quality infrastructure, and economic competitiveness. Changes in the racial and ethnic compositions of the population, specifically through international migration, could result in language barriers, which could require increased safety measures. Changes to mobility and transportation choice stemming from changes in the compositions of the population will indirectly affect quality infrastructure. More of these activities would be further concerned with a more multimodal transportation system that would be needed to support such changes. Changes in various components of the population, such as age, race and ethnicity, will indirectly affect economic competitiveness. As a destination for international migrants and ‘climate change refugees’, Florida is also likely to change its racial and ethnic

composition. Although the resulting population increase may lead to more job creation, many of these will be low skilled and labor-intensive.

Any changes in the components of the population will have cumulative impacts on environmental stewardship. The so-called “neighborhood churning” of a locale can disrupt social cohesion and neighborhood cooperation (Mennis, Dayanim & Grunwald, 2013). Consequently, these disruptions have the potential to negatively impact participation in environmental stewardship initiatives, in the short-term, at the local level. The consequences stemming from changes in the composition of the population focus on differing locational choices, mobility options, and the associated travel and quality of life preferences. The state currently lacks diverse travel choices in many areas outside of major urban areas. As the population changes, the state will need to provide mobility options for a more diverse population with different travel habits and preferences, in a greater diversity of contexts, particularly outside of urban centers.

Table 4. Impacts, Vulnerabilities, and Consequences Related to Demographic Changes

		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Population Change	Unanticipated changes in the level of population changes and the geographic distribution of those changes	Quality infrastructure Mobility Transportation Choice Economic Competitiveness	Safety and Security Quality Places	Environmental Stewardship	Moderate to High in the short term, High in the mid to long term	Greater increase in population results in unplanned increase in VMT congestion, and maintenance cost. Less growth (or decline) results in investments in the wrong places or for the wrong purposes.

Table 4. Impacts, Vulnerabilities, and Consequences Related to Demographic Changes (continued)						
		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Aging of the Population	Mobility and the cost of providing mobility options	Mobility Transportation Choice Safety and Security	Quality Places Economic Competitiveness	Quality infrastructure Environmental Stewardship	High in the short term, High in the mid to long term	Lack of mobility options for an aging population, particularly outside of urban areas Increasing cost of providing alternative transportation options Greater demand for service sector and health care-related VMTs Public safety issues
Generational Changes	Changing mobility options	Mobility Transportation Choice Quality infrastructure	Quality Places Environmental Stewardship	Safety and Security Economic Competitiveness	Moderate in the short term, Moderately High in the mid to long term	Changing demand for mass transit, More multimodal infrastructure, Diverging demands for alternative modes
Changes in the Components of Population	Lack of mobility options	Mobility Transportation Choice Quality Places	Safety and Security Quality infrastructure Economic Competitiveness	Environmental Stewardship	Moderate in the short term, Moderately High in the mid to long term	Lack of mobility options and different travel preferences for more diverse population, particularly outside of urban areas

Interaction with Potential Future FTP Scenarios

Florida's population projections show the potential for growth to return to historic rates of 800 or more people coming into the state every day. With this potential for

growth comes the uncertainty of planning and allocating resources for the changing population (Table 5). Although some scenarios propose that the population will return to historic growth rates, we must also be cognizant of the potential for a decline in population in pockets or throughout the state. The consequences of mismanaging and planning for increase of population may result in the misallocation of transportation funds to the expansion of capacity on roadways. Likewise, it may cause an investment in other mobility options that may primarily be beneficial to residents around the state that own and rely on personal vehicles.

Similar to Florida's scenario of a Return to Historic Growth, the Rural Rediscovery scenario brings other possibilities related to the expansion of the agricultural sector and ecotourism in the state's economy. Population change, whether it is caused by changing sectors of Florida's economy, environmental reasons, or simply due to increased land area and lower property values, has the possibility of leading to an inward migration of Florida's population. Rural Rediscovery may lead to unwanted and unnecessary suburban sprawl. This sprawl may perpetuate the issue of lack of diverse mobility options and may make it more difficult to invest in various transportation options due to the lack of dense development. Similarly, it may increase the need for freight deliveries to rural areas, which may be costlier to serve.

The potential for Florida's airports and seaports to become gateways for imports and exports may lead to the increase of job creation around the state. How the expanding economy of Florida links to the rest of the country and world will be a driver in the changing population for the state. This increase in Florida's economic growth and

position as a Global Trade Hub will create changing components of the population paralleling economic development.

With the development of Florida as a Global Trade Hub naturally comes the innovation of technology. As stated earlier, Florida's older adults are increasing at a rapid rate. Moreover, the rate of adoption of technology among older adults is occurring at a slower rate than for later generations. This creates additional uncertainty about how this component of the population will adapt to technological innovations and use them to access both transportation and other services, such as health care.

Similar to Florida becoming a Global Trade Hub, Florida also has the potential for becoming an Innovation Hub. Young, skilled workers would be establishing careers in the state and we need to be planning for the preferences that come along with Millennial workers. Young professionals are less dependent on personal vehicles. As a part of the generational changes, Millennials have much higher adoption rates of technology supporting the trends for technological use in the transportation sector and an increase in innovative solutions.

The Risks on the Horizon scenario encompasses in some way, shape, or form, the above scenarios presented in the FDOT Vision Element. How Florida will change is uncertain. There is the possibility that growth rates will return to a level below the estimated increase of 800 or more people per day. The continued increase in population depends upon a steady flow of migrants, both from other states and countries (Wang & Rayer, 2016). The connections between the FTP scenarios and population, demographics, and migration are textually represented in Table 5, as are the uncertainties of each area of concern and their associated consequences.

Table 5. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Population, Demographics, and Migration			
Scenarios from FTP	**Areas of Concern**	**Uncertainty leading to risk**	**Consequences**
Return to Historic Growth	Population Change	Planning for infrastructure and changing population	Misallocation of funds Lack of investment on other mobility options that benefits populations that do not own a personal vehicle.
	Aging Population	Gas prices stay low and new technologies don't catch up meaning there will be a continual dependence on personal vehicles	Older adults that do not have the ability to operate a personal vehicle have limitations in their ability to travel
	Generational Changes	Populations congregating on urban fringes along existing corridors	Shifting preferences in how younger and older populations are able to travel
	Changes in the Components of the Population	Changing race and ethnicity moving into the state	Language and cultural barriers
Rural Rediscovery	Population Change	Population change in the form of population growth may cause an inward migration due to increased amount of land and lower property values	This may lead to increased suburban sprawl. There may also be fewer mobility options in less dense areas for the various components of the population
	Aging Population	Older adults may choose to age in place in inland locations and populations migrating to Florida may choose to live in an inland environment	If aging population is shifting to rural environments it is difficult to implement public transportation and justify the implementation is development is not dense enough
	Generational Changes	Older people: age in place and automobile dependent Millennials Locate in dense areas, less car dependent	Diverging preferences. Patterns of lifestyle choice/stage behaviors may converge or diverge
	Changes in the Components of the Population	Agricultural sector expanding	
Global Trade Hub	Population Change		Changing component of the population paralleling economic development
	Aging Population	Adoption rates of technology Dependency on services (health care).	Changing economic identity in relation to the healthcare sector (more broad than healthcare)
	Generational Changes	Florida becomes a prime location for multinational headquarters of companies working in the U.S., Caribbean, and Latin America	Potential for bringing in a larger portion of younger generations working in these sectors/industries and having to accommodate for their travel needs and preferences
	Changes in the Components of the Population	Changing in diversity of travelers to Florida	Language and cultural barriers

Table 5. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Population, Demographics, and Migration (continued)			
Scenarios from FTP	**Areas of Concern**	**Uncertainty leading to risk**	**Consequences**
Innovation Hub	Population Change	Young, skilled workers establish careers in Florida because of high quality careers and booming economy	Planning for preferences of younger populations
	Aging Population	More people choose to lie in urban areas so they can work, live, play and learn in denser urban cores	Planning for older adults that do not use or have access to a personal vehicle and depend on other forms of travel in a dense urban core
	Generational Changes	Influx of younger populations will bring new hubs of knowledge allowing for growth if innovative industries	Planning for needs and different travel patterns among younger population that may be less dependent on a personal vehicle.
	Changes in the Components of the Population	Changing mobility options Changes in preferences	Acceptance (digital divide b/w generation and ethnicities) and adaptability (aging and language divides)
Risks on Horizon	Population Change	Migration and overall population slows within state of Florida	Misallocation of or reduction of funds and resources
	Aging Population	Numerous hurricanes hit Florida in a year	The evacuation of older adults numerous times and establishing care for them as they are moved around the state.
	Generational Changes	Younger migrants and retirees	Matching investment to transitioning lifestyle choices
	Changes in the Components of the Population	Florida's economy enters a period of stagnation do to extreme weather events	We lose younger components of the population that moved to Florida for its innovative economy

Table 6 summarizes the likelihood, frequency, vulnerability, threshold, and consequences regarding population, migration, and demographic risks. For the risks related to allocation of funds, mode options for older adults, evacuation of vulnerable populations, and increases in VMT and congestion, the likelihood is expected given current planning processes regarding population growth and change. Changes in vehicle ownership and mode preference have probable likelihoods due to generational changes and increases in the availability of share modes of travel. The risk related to greater demand on infrastructure is likely since Florida's population is growing at a rapid rate. As for frequency, many of the population risk are ongoing including the allocation

of funds, mode options for older adults, increases in VMT and congestion, greater demand on infrastructure, and equitability of accessibility. While many population-related risks do not have thresholds, changes in vehicle ownership and mode preference have thresholds that could affect many of the transportation outcomes, such as VMT and congestion. Changes in vehicle ownership and a mode preference away from automobiles could increase the risk associated with evacuations during major storm events. While vulnerability and consequences related to population, migration, and demographics are discussed heavily in previous sections, the extreme consequences of increases in VMT and congestion, changes in vehicle ownership, and changes in mode preference are highlighted as important considerations.

Table 6. Population, Migration, and Demographic Risk Matrix					
Risk	Likelihood	Frequency	Vulnerability	Threshold	Consequences
Allocation of Funds	Expected	Ongoing	High	No	Moderate
Mode Options for Older Adults	Expected	Ongoing	High	No	Moderate
Evacuation of Vulnerable Populations	Expected	Near future	High	No	Moderate
Increases in VMT and Congestion	Expected	Ongoing	Moderate	No	Extreme
Greater Demand on Infrastructure	Likely	Ongoing	High	No	Moderate
Changes in Vehicle Ownership	Probable	Near future	Moderate	Yes	Extreme
Changes in Mode Preference	Probable	Near future	Moderate	Yes	Extreme
Equitability of Accessibility	Unlikely	Ongoing	Moderate	No	Minor

Economic and Revenue Risks

Personal income and employment have largely been assessed separately throughout this project. However, the synergies between the two have been noted and continually expanded upon. In this final report, the synergies become even more interconnected as we move from the lower level categories of personal income and employment towards looking at how the economy might change and what this means for transportation-related economic development goals that can influence both personal income and employment, together and separately.

The risks stemming from changes in the economy include the transitioning demand of labor skills (particularly within the transportation sector), the impact of automation, and the influence of the creative class. The changing employment in transportation will have a direct impact on the number and types of jobs available (see Technical Memorandum 2). As automated driving systems are introduced, drivers will be needed less. Once the tipping point towards automation is reached, unemployment among drivers will increase at a rapid rate. With technological advancements, the nature of jobs will change and will result in an increased demand for skilled laborers who can remotely operate vehicles (e.g., drones, autonomous vehicles (AVs)). This changing demand for skilled labor will lead to job risks and staff retention risks. In addition, there will be pressure for training programs for workers to transition from one type of skill to another. The changing job dynamics will have an effect on the transportation sector.

As technological operations and maintenance increase demand for employment, the creative class, and those that are in non-traditional high-skill and high-paying

sectors, may move to Florida to take these positions, unless they chose to work remotely. Some of them will shift to Florida and generate more employment opportunities. In turn, these higher skill jobs will increase the level of personal income, and result in more secondary and tertiary employment, which results in increasing economic activity. Moreover, while the automation of vehicles will reduce the number of driver related positions, it will also lead to job growth in tertiary sectors related to the movement of goods and people, such as specialty mechanics, human monitors, and specialty cleaners.

Any changes in the employment sector of transportation are not the only type of employment change that will affect the transportation system. The increasing trends of job growth in urban environments will require more infrastructure and services that are more efficient. Therefore, increasing the connectivity between and within urban environments via multiple modes will be essential in growing the state's economy, particularly in the South Florida (SoFlo) Megaregion.

Changes in transportation revenues, particularly revenue shortfalls, also pose a risk to the transportation system. Vehicles are becoming more efficient, changing to alternative energy sources, and policy mandates from all levels are looking to increase sustainability and reduce pollution and emissions from the highest polluting sector in the United States. These impacts will intensify with the introduction of other technologies, such as telecommunications, wireless communications and other related technologies, which affect travel behavior. This is particularly problematic for the state, as Florida's transportation system heavily relies on the revenue generated through fuel taxes (Pula, 2018), while presently having a limited number of user charges for system users. As

such, Florida is facing risks of revenue shortfalls and aging infrastructure, as well as challenges with matching transportation choices with changes to the economy. Thus, varying levels of uncertainty and vulnerability surrounding personal income, fuel tax, and employment lead to risks within the broad source of risk of shifting economic activities and changing levels of revenue generation, as shown in Table 7.

Table 7. Uncertainties Leading to Risk in the Transportation System Related to Economics and Revenue

Area of Concern	Potential Uncertainty	Potential Vulnerabilities	Assets Affected	Level of Vulnerability	Consequences of Each Type of Uncertainty	Risk
Personal Income	State of economy (State and National) Macro economic factors (e.g., oil spill, pollution)	Short and long term transportation infrastructure maintenance, Revenues, Demand for new and/or alternative modes of transportation	All modes of transportation infrastructure	Low to moderate risk in short term; high risk in mid-to-long term	Impact on general mobility and connectivity Loss of economic efficiency Higher operational and infrastructure maintenance cost May impact transportation safety and security Impact on health and quality of life	Pressure /deterioration of transportation infrastructure (especially on airports and seaports)
Fuel Tax and Automotive Advancements	Global crude prices, Global conflicts, Macro economic variables. Examples* Environmental variables and consciousness	Declining investment in transportation infrastructure in long term and reduced quality	Change in revenues for infrastructure investment, especially roadways	Moderate to high risk in short term; high risk in mid-to-long term	Potential change in gas tax revenue which may affect maintenance and operations of transportation infrastructure Mobility and connectivity will be affected Impacts on existing and future projects	Budgetary constraints Alternative revenues sourcing Alternative fuel impact on the vehicle sale

Table 7. Uncertainties Leading to Risk in the Transportation System Related to Economics and Revenue (continued)						
Area of Concern	**Potential Uncertainty**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of Each Type of Uncertainty**	**Risk**
Employment	Sectoral change in employment adversely affecting job creation of high paying job in transportation sector.	Creation of more low paying jobs from tourism	International trade, freight, aviation, Market share of trade	Low to moderate risk in short term; high risk in mid-to-long term	May impact number and types of jobs Potentially affecting quality of life Low jobs in transportation sector will impact mobility and connectivity	Staff retention Transitioning demands of labor skills (Transferability of skills) Transition from one level of necessary skilled level to another Impacts on jobs due to shift to AVs Influence of the creative class / quaternary class

Interactions with FTP Goals

Any change in personal income directly influences VMT and congestion, as well as mode choice. As a result, personal income directly affects three FTP goal areas, economic competitiveness, mobility, and transportation choice. Personal income has a direct effect on economic competitiveness as an increase in personal income results in more investment and expansion in the state to compensate for the growing consumerism stemming from such increases in income. Furthermore, increases in personal income can lead to increases in job creation and ongoing development, while also having the potential to increase disposable income, which increases spending in a variety of sectors including travel, tourism and retail. This will subsequently lead to increased traffic at our major ports, warehouses and other freight facilities, further increasing the economic competitiveness of the state.

Additionally, an increase in personal income generally leads to an increase in VMT and congestion, affecting mobility and transportation choice, increasing the need for alternative modes of transportation and methods to reduce VMT and congestion. However, a decrease in personal income will negatively affect economic competitiveness; as such, a decrease will not promote future investment and expansion of businesses. Likewise, a decrease in personal income reduces VMT and the associated revenues generated from fuel tax and other related revenue sources. Lastly, a decrease in personal income could affect the mobility choices for large segments of the population, leading to higher demand for public transportation.

In addition to the direct effects, changes in personal income indirectly affect the FTP goal areas of safety and security and quality infrastructure. Personal income affects safety and security through the abovementioned relationship between personal income, VMT, and congestion. Furthermore, an increase in income leads to an increase in the purchase of goods and services resulting in increased freight and port traffic, putting further stress on the security measures taken at these critical infrastructure points. Similarly, the resulting increases in VMT and congestion from increases in personal income necessitate more frequent maintenance operations, due to the increased wear and tear on roadway infrastructure. However, at the same time, the increased road traffic further delays these operations leading to ongoing deterioration of roadway infrastructure.

Two goals areas are affected by cumulative impacts stemming from changes in personal income: environmental stewardship and quality places. Increases in personal income can affect environmental stewardship by spurring growth in development,

leading to sprawl, necessitating the consumption of additional conservation land. However, at the same time, increases in personal income results in higher socioeconomic status, which often positively correlate with increased awareness and concern over the environment (Everett & Pierce, 1992). Moreover, increases in personal income can lead to further urbanization from growing economic epicenters (Alig, Kline, & Lichtenstein, 2004), leading to a buildup of infrastructure rather than outward sprawl. This simultaneously affects the goal of quality places as development patterns of vertical development versus horizontal development can have a multitude of impacts. Thus, the consequences of changes in personal income largely relate to changes in travel patterns and behaviors, changes in road infrastructure usage rates, and changes in revenues generated directly through additional taxes and fees, including fuel taxes.

Fuel tax and automotive advancements directly affect two goal areas of the FTP: economic competitiveness and quality infrastructure. The revenues from fuel taxes are expected to decrease through the increasing use of fuel-efficient vehicles and the transition to vehicles using alternative energy sources (i.e. hybrid and electric vehicles). A reduction in fuel tax revenues would threaten any advancements in infrastructure and equipment, making for a less effective transportation system, which could dissuade businesses with high transportation costs from relocating or expanding in the state. Similarly, changes in fuel tax revenues directly affects the FTP goal of quality infrastructure, due to the financial reliance on this source of revenue for transportation investment, maintenance and operations, whereas mobility and transportation choice will be indirectly impacted through changes in fuel tax revenues and automotive advancements. As such, environmental stewardship would be cumulatively and

positively impacted through automotive advancements. However, the consequences are that without additional revenue sources, the declining revenue from the state's primary source will hinder investment opportunities and delay the introduction of advancing transportation technologies, like that of fully connected and autonomous vehicles (CAVs), due to lack of funding for necessary infrastructure.

Changes in employment directly affect two goal areas of the FTP: economic competitiveness and mobility (Table 8). According to the FTP Vision Element, "Robotics and automation could revolutionize transportation system maintenance and freight delivery practices" (FDOT, 2015a, p. 7). As a result, employment will change through technological advances. While automation could reduce the number of jobs, it is also possible that it could create different employment opportunities. Replacement of driver-oriented jobs with higher paying technologically-oriented transportation jobs would lead to higher personal income and likely increase disposable income, which as discussed above, directly affects the economic competitiveness of the state. Similarly, both the rise in income from the jobs created through technological advancements in the transportation industry and a more efficient and advanced transportation system will result in new technology-related employment that will directly affect mobility. Changes in employment will be matched with increases or decreases in the need to travel without delays and with reliable travel time.

In addition to the direct effects of changes in employment within the transportation sector, three goal areas of the FTP – transportation choice, quality places, and quality infrastructure - would be indirectly affected. The aforementioned transition to incorporate various transportation-related technologies would not only lead

to better job opportunities, economic prosperity, and social stability of the transportation sector workforce, but also necessitate the expansion of educational opportunities to train employees to successfully transition from the current lower skilled employment to technology-driven employment. Changes in the transportation workforce will directly impact transportation choice and indirectly affect quality infrastructure through the technological advancements of this sector. As is discussed below, automation and other forms of improving transportation, such as enhancing ride-hailing services and public transit systems, could lead to a more agile and resilient transportation system. The changing employment in transportation will cumulatively affect safety and security, due to the reliance on human monitors and the use of improved logistic cooperation. Safety and security measures would go through a period of constant changes and updates in parallel with the adoption and deployment of AVs and other technological advancements.

The consequences of changes in employment within the transportation sector due to advancing transportation technologies, such as automation, center on the tradeoffs between larger scale losses of lower-skilled service positions in lieu of a smaller creation of high-skilled, quaternary sector job opportunities and the ensuing economic multiplier effect. Automation will reach a tipping point that will result in mass layoffs of drivers and a short-term shock in unemployment rates of workers without transferable skills. As such, the state needs to plan for this transition both through investments in the technology and in educating and training the technologically-oriented workforce of the future.

Table 8. Impacts, Vulnerabilities, and Consequences Related to Economics and Revenues						
		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Personal Income	Increase in personal income results in increase in VMT and Congestion. Decrease in personal income results in decrease of VMT and Congestion. Mode choice varies in association with personal income	Mobility Transportation Choice Economic Competitiveness	Safety and Security Quality Infrastructure	Environmental Stewardship Quality Places	Low to moderate risk in short term; high risk in mid-to-long term	Changes in revenues Change in travel patterns and behaviors Change in road infrastructure usage rates
Fuel tax and automotive advancements	If fuel usage affects revenues both positively and negatively Automotive advancements increase efficiency reducing fuel tax revenue.	Economic Competitiveness Quality infrastructure	Mobility Transportation Choice Safety and Security Environmental Stewardship	Quality Places	Moderate to high risk in short term; high risk in mid-to-long term	State will need to identify other sources of revenue, Changing energy source infrastructure Global trade relationships
Employment	Changing nature of transportation employment	Economic Competitiveness Quality Places Mobility Quality Infrastructure	Quality infrastructure Transportation Choice	Safety and Security Environmental Stewardship	Low to moderate risk in short term; high risk in mid-to-long term	Change in skill level of jobs in transportation Potential unemployment shock for drivers with limited skills Economic multiplier effect

Interaction with Potential Future FTP Scenarios

The Return to Historic Growth scenario focuses on the high growth in population and the economy with the same development patterns of today. The domestic in-

migration will bring higher skilled workers who will have higher personal incomes (Table 9). This will lead to changes in travel patterns, such as increases in driving or more traveling and more consumption of goods. This will increase congestion and put pressure on the existing transportation infrastructure. In contrast to in-migrants, immigrants will initially have fewer skills and less personal income in general. Immigrant households typically have lower vehicle ownership rates and are more reliant on public transit, which will cause more strain on existing public transit systems. In addition, immigrants with limited abilities to speak English will experience slower economic integration.

Fuel costs will affect the Return to Historic Growth scenario. If fuel costs continue to stay low and automobile advancements continue to happen, there will be a direct impact on car ownership and mode choice. Lower fuel costs induce more vehicle sales leading to higher car ownership rates. This will lead to increasing pressure on existing roadways and highways due to increased VMT and congestion. On the contrary, if the automotive advancements do not happen and there is rise in fuel cost, then the demand for public transit, where available, will increase because it will be more affordable to use public transit in comparison to owning a car. For households that live in areas without convenient transit service, residents will pay more for transportation services or reduce the number of trips they take. Thus, the price of energy is likely to affect the allocation of funds between public transit and roadway infrastructure.

The Rural Rediscovery scenario focuses on increasing economic activity in rural areas. Urban areas have typically higher levels of personal income than rural areas. Therefore, if rural rediscovery were to occur it will result in population decentralization,

which will have implications on the municipal services. At the same time, many rural communities will continue to depend upon nearby urban centers for employment, and goods and services. It will cost more money to have facilities further away from the center of the city and there will be a need for more transportation infrastructure. Therefore, it will put strain on the municipal service budget through rural rediscovery.

Furthermore, rural rediscovery will result in sprawl, which may result in more VMT and congestion. These both will positively impact the fuel tax because they will result in higher levels of fuel consumption. However, through the adoption and deployment of automotive advancements, there will be a transition to more fuel-efficient or alternative-fuel vehicles, which will reduce tax revenues from fuel sources, unless the state imposes additional fuel taxes. Thus, through Rural Rediscovery, there is likely to be increases in VMT and congestion, without increases in associated revenues.

The Global Trade Hub scenario focuses on the expansion in global trade, tourism and investment, which would all have positive influences on personal income. Higher personal income will increase demand leading to greater consumption of goods. This will have direct impact on becoming an established global trade hub by creating more pressure on the ports, rails, and road infrastructure. People with higher incomes travel more, which will put additional pressure on airports, seaports, and roads. There will be a need for sufficient transportation infrastructure to handle the increase in demand for travel and the consumption of goods. There will also be a need for airport and seaport upgrading and expansion to serve this demand.

Furthermore, due to global trade expansion, the vulnerability lies in how AVs could influence the expense to transport goods, which may alter the freight market and

the logistics of trucking demand. The increase or decrease in crude oil prices affects global trade movements directly. The automotive advancements impact the crude oil prices, which indirectly impact the trade movement. The high oil prices might promote the use of alternative energy sources while the people may choose to travel less. Due to higher crude oil prices, less freight will be shipped, and the production of goods will likely decrease. At the same time, less expensive crude oil prices will induce higher freight demand.

The Innovation Hub scenario focuses on technological innovation that would allow the state to become a global leader in life sciences, information technology, aerospace and other innovation industries. Due to such technological investments, Florida would attract more creative/quaternary class employment resulting in increasing economic activities in existing urban centers and a larger number of skilled persons with higher personal income. This will lead to changes in travel patterns and an increased consumption of goods. However, the nature of the changes in travel patterns will depend upon the lifestyle behaviors of Millennials, who dominate creative class employment, demographically speaking. If Millennials exhibit lifestyle and travel patterns similar to older generations, the change to an innovation hub economy could lead to additional travel. If, on the other hand, a significant portion of Millennials chooses to live in more urban environments and engage in multimodal travel, the state and regional governments will need to plan for these more diverse travel patterns.

The Risks on Horizon scenario focuses on the future risks due to slowing population growth, economic uncertainties, and climate change. The risks will lead to the uncertainty in personal income. Personal income might increase or decrease. This

will have positive or negative impacts on congestion and VMT. Automotive advancements will decrease the revenues generated from the fuel tax leading to the risk that there will not be adequate funding for transportation investments and maintenance. Currently, the rate and speed of adoption is highly uncertain. The speed with which drivers adopt improved energy efficiency, EVs and AVs, will affect the timing of the decrease in tax revenues for the transportation system. Implementation of automotive advancements will result in uncertainty about the amount of transportation-related employment. These changes might lead to more job creation among higher-skilled technology-based operations and maintenance positions at the same time that driver positions, such as long-haul trucking and sharing economy jobs, are lost.

Table 9. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes the Economy and Revenues

Scenarios from FTP	**Area of Concern**	**Consequences type of uncertainty**	**Risk**
Return to Historic Growth	Personal Income	Increase or decrease in personal income based on the skills and language ability of population	Change in transportation choice Pressure on transportation infrastructure (public transport)
	Fuel Tax and Automotive Advancements	Rate of adoption of energy efficiency and automotive advancements would have direct impact on car ownership and mode of travel.	Increase in congestion Stress on existing roadways especially highway system
	Employment	More jobs created in agriculture, trade and tourism	Pressure on the transportation system
Rural Rediscovery	Personal Income	Economic/population decentralization will cost more money to provide services	Strain on municipal services budget
	Fuel Tax and Automotive Advancements	Beneficial for fuel tax revenues prior to automotive advancements	Sprawl increases VMT and congestion causing more fuel consumption while increasing revenues Increasing use of fuel efficient cars reduces tax revenues
	Employment	Need of roadways connecting farm to market to support additional agricultural employment	Pressure on Transportation budget and funding

Table 9. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes the Economy and Revenues (continued)

Scenarios from FTP	Area of Concern	Consequences type of uncertainty	Risk
Global Trade Hub	Personal Income	Higher personal income will increase consumption of goods with direct impact on global trade hub. More pressure on the ports, airports, rail and road infrastructure Higher income people travel more, which will put pressure on airports and roadways	Freight movement Sufficient capacities of transportation infrastructure (rails, roads, airports and ports) to handle this pressure of global trade
	Fuel Tax and Automotive Advancements	Fuel efficient or alternative fuel vehicles for freight movement and shipping goods as well as for tourist's mobility	Crude oil consumption Cost of shipping goods
	Employment	Expansion of global trade and tourism will lead to generation of more employment demand leading to higher levels of consumption.	Better employment results in higher level of consumption Optimizing mobility of goods, services, and human capital
Innovation Hub	Personal Income	Due to advancement of technology, more creative/quaternary class employment will be attracted to Florida leading to higher personal income. Changes in travel pattern and consumption of more goods.	Pressure on transportation infrastructure
	Fuel Tax and Automotive Advancements	Change in energy source leads to cheaper travel and increased travel demand.	Cheaper travels will increase congestion
	Employment	Opportunities for higher skill labor will increase. Influx of people to the state of Florida this will generate pressure on urban centers.	More congestion in urban centers. More pressure on urban transportation
Risk on Horizon	Personal Income	The increase in personal Income will put pressure on the transportation infrastructure. Decrease in personal income will put stress on public transportation.	Increased usage of transportation infrastructure will lead to its deterioration. Airports and seaports might exceed their capacity and expansion will be needed Need for public transportation investments to support changing population

Table 9. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes the Economy and Revenues (continued)			
Scenarios from FTP	**Area of Concern**	**Consequences type of uncertainty**	**Risk**
Risk on Horizon (continued)	Fuel Tax and Automotive Advancements	The revenues generated from the fuel tax is not enough for transportation infrastructure investment and maintenance.	Revenues generation at risk. Need for alternative revenues sourcing.
	Employment	The implementation of automotive advancements will bring uncertain changes to the transportation employment. Unknown technology adoption results in unknown changes in employment	Uncertainty in employment

Table 10 summarizes the likelihood, frequency, vulnerability, threshold, and consequences regarding economics and revenues. For the risks related to budget constraints, changes in revenues, fuel efficiency and revenue, and alternative fuel and revenue sources, the likelihood is expected given current planning processes regarding the state's current revenue sources and economic trends. Personal income is likely to change due to current employment and income trends. Conversely, the likelihood is probable regarding the impact of automation, transition demand of labor skills, and influence of the creative class. As for frequency, budget constraints, fuel efficiency and revenue, change in personal income, and the influence of the creative class are all ongoing risks. Changes in revenues and alternative fuel and revenue sources are expected to impact Florida in the near future. Considering their scope, the impact of automation and the transitioning demand of labor skills are long term in regards to frequency. While many economic and revenue risks do not have thresholds, alternative fuel and revenue sources, the impacts of automation, and, the associated transition in demand for higher-skilled labor skills possess thresholds based on the pace of adoption

of transportation advancements, such as the use of transition fuels (likely electric), and AVs, respectively.

Table 10. Economics and Revenues Risk Matrix					
Risk	Likelihood	Frequency	Vulnerability	Threshold	Consequences
Budget Constraints	Expected	Ongoing	High	No	Extreme
Changes in Revenues	Expected	Near future	High	No	Extreme
Fuel Efficiency and Revenue	Expected	Ongoing	High	No	Extreme
Alternative Fuel and Revenue Sources	Expected	Near future	High	Yes	Moderate
Change Personal Income	Likely	Ongoing	Moderate	No	Moderate
Impact of Automation	Probable	Long term	High	Yes	Extreme
Transition Demand of Labor Skills	Probable	Long term	Moderate	Yes	Moderate
Influence of Creative Class	Probable	Ongoing	Moderate	No	Moderate

Environment

Risks

As stated in previous technical memoranda, the most-pertinent environmental areas of concern to the transportation system are sea level rise and storm surge, increasing hurricane intensity, temperature increases, and an increase in heavy precipitation events. Technical Memorandum 3 identified the risks associated with each of these environmental areas of concern and related the risks back to the FTP scenarios. The following section summarizes the environmental risks to Florida's transportation system and how these risks create issues for the future.

The first environmental area of concern, and the most pertinent, is sea level rise and storm surge. Increasing sea levels will affect coastal property and transportation infrastructure through more damaging storm surges and waves and eventual permanent submersion. The risks associated with sea level rise and storm surge are the loss of infrastructure and property due to permanent submersion, damage to the structural integrity of infrastructure from prolonged periods of temporary flooding, changes in future population distribution, and changes in mobility patterns due to flooding and population changes. Coastal areas will encounter loss of mobility and loss of services, and an overall reduction in the movement of goods, services, and human capital. The current and future populations impacted by SLR will become climate refugees and new migrants affecting the demand for travel and inland infrastructure. Florida can expect a low to moderate risk in the short term, and a high risk in the long term if sea level rise and storm surge are not addressed in today's planning processes.

Due to warmer waters and higher sea levels, the Atlantic Ocean is expected to experience an increase in more intense hurricanes. Effects of more intense hurricanes

include damage to and temporary flooding of transportation infrastructure, disruptions in the transportation network, impediments to the flow of goods and people, complications to emergency evacuation routes and protocols, and high economic costs from damages and loss of revenues. Thus, there are risks to the transportation system in two main ways: 1) coastal transportation infrastructure along the coast at-risk, including roads, seaports, automobiles, flights, buses, and rail, and 2) efficiency of evacuation practices to address evacuation of all modes of transportation, including automobiles, flights, and buses. This risk also includes the evacuation for those without a personal vehicle and sheltering in place. With increasing hurricane intensity, there is a low to moderate risk in the short term and a high risk in the mid-to-long term. Although hurricane intensity poses a moderate risk to the current transportation system, there will be higher risk in the future if hurricanes continue to intensify and if the risks are not mitigated.

Temperatures have risen in the United States for the past few decades, mainly due to climate change and global warming (USGCRP, 2018). Extreme heat can cause a variety of issues to transportation systems including more rapid deterioration of roadways and runways necessitating increased frequency of maintenance, buckling of concrete and steel, delays in construction due to worker safety, and an exacerbation of the urban heat island effect. Thus, there are risks associated with temperature increases to the transportation system in a couple of ways: 1) maintenance of transportation system, and additional, more frequent maintenance and the associated costs; and 2) temperature-related delays in the transportation system in relation to construction and maintenance. Higher temperatures pose a low risk in the short term, but a mid-to-high risk in the mid-to-long term. The progression from low to high risk over

time is attributed to the fact that the impacts of climate change and global warming will continue to worsen if we do not take any action to reverse.

Another environmental risk is an increase in heavy precipitation events, which has been observed throughout the United States (Walsh et al., 2014). This means that for a rain event, there is an increase in how much rainfall is dumped during it. For Florida, temporary flooding caused by an increase in heavy precipitation events would create risk to the transportation system in many ways, including impacts to the structural integrity of roads, runways, and rail bases, network disruptions, and higher weather-related crash rates. Thus, there are risks to the transportation system in a few ways: 1) structural integrity of the transportation system in relation to soil permeability and soil integrity from increased heavy precipitation, and 2) network disruptions and weather-related accidents from temporary flooding. An increase in heavy precipitation events poses a low risk in the short term, and a moderate to high risk in the mid-to-long term due to the potential uncertainty of future emissions levels, global warming, and changes in ocean circulation patterns.

Table 11. Uncertainties Leading to Risk in the Transportation System Related to the Environment

Areas of Concern	**Potential Uncertainties**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of each type of uncertainty**	**Risk**
Increased Hurricane Intensity	Future warming of earth and oceans; Emissions levels; Change in ocean circulation patterns	Damage to coastal property and infrastructure due to: wave impacts; hurricane force winds; flooding and overtopping of surface transportation; saturation of roadbeds, runways, and rail beds.	All modes of transportation infrastructure.	Low to moderate risk in short term; high risk in mid-to-long term	Transportation network disruptions, loss of service, and loss of connectivity. Travel delays due to evacuations, debris, and canceled service (flight, rail, transit).	Coastal transportation infrastructure at risk Efficiency of evacuation all modes of transportation and households those without a personal vehicle.

Table 11. Uncertainties Leading to Risk in the Transportation System Related to the Environment (continued)						
Areas of Concern	**Potential Uncertainties**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of each type of uncertainty**	**Risk**
Sea Level Rise and Increased Storm Surges	Future warming of earth and oceans; Emissions levels; Melting of land-based ice	Damage to coastal property and transportation infrastructure due to: flooding and overtopping of surface transportation; saturation of roadbeds, runways, and rail beds; corrosion from repeated saltwater exposure.	All modes of transportation infrastructure located in the coastal zone	Low to moderate risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service, and connectivity due to flooded roadways.	Proactive versus reactive planning for sea level rise and permanent flooding Structural integrity of roads, bridges, seaports, airports, and other critical infrastructure in the coastal zone Loss of mobility and services, and an overall reduction in the movement of goods, services, and human capital Current and future populations impacted by SLR; climate refugees and new migrants impacting inland infrastructure
Tempera-ture Increases	Emissions levels	Softening and expansion of pavement causing ruts and potholes; potential stress on bridge joints. Delays in construction and maintenance, as heat waves limit construction activities	Roadways and runways (pavement)	Low risk in short term; moderate to high risk in mid-to-long term	Network disruptions due to road damage and construction and maintenance delays. Potential for the creation of urban heat islands	Maintenance of transportation system, and more frequent maintenance + associated costs Temperature-related delays in the transportation system in relation to construction and maintenance
Increase in Heavy Precipita-tion Events	Future warming of earth and oceans; Emissions levels; Change in ocean circulation patterns.	Erosion and subsidence of roads, runways, and rail bases. Increased scouring of bridge supports. Increase in weather-related traffic accidents.	All modes of transportation infrastructure.	Low risk in short term; moderate to high risk in mid-to-long term	Network disruptions due to flooded facilities and crashes. Faster deterioration of transportation facilities. Increase in traffic-related injuries and fatalities.	Structural integrity of the transportation system related to soil permeability integrity from increased heavy precipitation Network disruptions and weather-related accidents from temporary flooding

Interaction with FTP Goals

Sea level rise and increased storm surges will have various direct impacts on the transportation system, especially in coastal low-lying areas. Sea level rise and increased storm surges will directly impact the goal of quality infrastructure, as permanent inundation and periodic flooding will deteriorate roads, rails, bridges, and other transportation infrastructure, and compromise storm water infrastructure (USGRPC, 2018). Similarly, mobility and transportation choice will be directly impacted by sea level rise through permanent inundation and periodic flooding from increased storm surges. Sea level rise will create permanent inundation in coastal areas, thus reducing the mobility and transportation choice of the area in all transportation sectors, including public transit, walkability, and cycling.

In addition, safety and security will be directly impacted due to sea level rise and increased storm surges; this is especially apparent when analyzing the safety and security impacts to seaports and other coastal transportation infrastructure. With increasing storm surges, which are exacerbated by sea level rise, the safety and security of seaports and other coastal infrastructure would be compromised during a storm, hurricane, or heavy rain event. Coastal infrastructure is more vulnerable during these storm events; compounded with sea level rise, there will be direct impacts to coastal safety and security. Sea level rise and increased storm surges may further affect safety and security to inland areas due to inland and nuisance flooding.

Lastly, sea level rise and increased storm surges will directly affect environmental stewardship, since the preservation of coastal areas is integral to conservation planning for coastal species. The loss of coastal resources includes mangroves and other coastal vegetation that provide soft armoring against hurricanes,

beach dunes that also offer protection, and coastal species like sea turtles that bring culture and environmental awareness to the community (USGCRP, 2018). For the transportation system, environmental stewardship would be impacted through the loss of these coastal resources, which may increase the need for adaptation and resilience along the coast, especially for the roadway networks and seaports, if these soft armoring elements are lost. Additionally, there may be a need to build new roads and other infrastructure to compensate for the transportation infrastructure lost to permanent flooding; this impacts environmental stewardship by increasing development in other areas and could lead to further loss of biodiversity.

Since sea level rise is a continuous and gradual process, there will be indirect impacts that stem from the processes and actions occurring today. One of the major indirect impacts may be to Florida's economic competitiveness. As the state experiences sea level rise and related direct impacts, mainly permanent inundation, coastal areas may become less desirable to tourists and potential residents. Furthermore, permanent inundation would eventually reduce access to critical facilities, such as ports, reduce property values, and, ultimately, reduce the mobility of goods, services and people, which would affect the economic competitiveness of the state. As nuisance flooding or sunny-day flooding becomes more frequent in the coming years, potential residents and investors may be deterred from moving to Florida by the vulnerability of coastal areas to sea level rise and nuisance flooding.

The indirect impacts related to sea level rise will eventually lead to cumulative impacts on the goal of quality places. The continuous process of sea level rise will result in a growing area of permanent inundation if no adaptation actions are taken to prevent

or mitigate the direct impacts of sea level rise. Properties, both coastal and inland, will begin to experience permanent inundation and losses in connectivity to the transportation network. All modes of transportation would be impacted, including cycling, vehicular, pedestrians, and public transit options, especially along the coast. Overall, this affects the creation of quality places, since sea level rise poses a threat to the residents in the area and the visiting tourists.

With increased hurricane intensity, there will be direct impacts to quality infrastructure, mobility, transportation choice, and safety and security. Stronger hurricanes will result in more damages, which will then affect the goal of quality infrastructure related to recovery from the storm and resilience from future storms. Increased hurricane intensity may result in longer storm durations, which would further affect the low mobility and transportation choice before, during, and after a hurricane. Evacuation routes, access to gas and water, and emergency shelters are the three main challenges to mobility and transportation choice during a hurricane; oftentimes gridlocks caused by frantic drivers and concentrated evacuations. This leads into the direct impacts on safety and security, where gridlocks and poor mobility and lack of transportation choices can compromise the safety of the individual and the traveling public. Other ways that stronger hurricanes can directly impact safety and security include loss of communication lines, disruption with emergency services, and disconnection from critical infrastructure, like police stations and evacuation shelters. Increasing hurricane intensity will have direct impacts to environmental stewardship as well, as stronger hurricanes will deteriorate coastal ecosystems and resources (Meeting 3).

As hurricanes become more frequent and intense, there may be future indirect impacts on Florida's economic competitiveness. Hurricanes are multi-day emergency events that not only destroy homes and property, but they also put the economy in stasis for the impacted area. Additionally, the economic costs of hurricanes significantly affect the state's economic competitiveness. The level of economic activity will increase in areas with major damage from hurricanes during the rebuilding. However, residents directly impacted by hurricanes may take months to years to recover from the hurricane and some will never recover and may leave the state. More intense hurricanes may also act as a deterrence for future tourists and residents, thus reducing economic competitiveness through decreased tourism and a stagnant population.

The cumulative impacts of increased hurricane intensity include impacts on quality communities. Increased hurricane intensity will undeniably cause major structural damage, thus reducing overall quality of life. These structural impacts include damages to roads, bridges, rails, buildings, schools, and public infrastructure, like power lines and municipal buildings. All aspects of the community may be affected by hurricanes, which may increase the duration of the hurricane and its response and recovery. Communities that are directly impacted by hurricanes can take years to recover due to the impact of these events. Ultimately, a hurricane can change the economic prosperity, educational opportunity, social stability, and community cultural activities of residents – all of which relate to the creation of quality places.

Increases in temperature will directly affecting the goal of an agile, resilient and quality infrastructure, mobility, and transportation choices during an extreme heat event and in its aftermath. Temperature increases are expected to limit construction activities,

increase the need for refrigerated freight movement, and decrease vehicular movement during the event (Jacobs et al., 2018). The overall impact is a temporary, and, sometimes, permanent reduction in mobility and transportation choice, and increased costs of associated with the goal of quality infrastructure (Meyer et al., 2014). On a practical level, residents and visitor may change their transportation choices to avoid spending extended period in the heat. Additionally, environmental stewardship will be directly impacted since hotter temperatures will change the biosphere, thus changing local habitats and ecosystems.

The indirect impacts of temperature changes will arise gradually due to the long-term effects of increasing temperatures. Due to the potential of urban heat islands affecting Florida, cities will become warmer and indirectly affect the economic competitiveness of Florida. Temperature increases will indirectly affect economic competitiveness through the deterioration of roads through pavement expansion, bridge joint deterioration, rail buckling, and related construction and maintenance delays. Similarly, these disruptions and delays to the transportation system may cause increased traffic, which would reduce productivity related to the state's economic competitiveness. Increasing temperatures will also have cumulative impacts on Florida's goal of quality communities. Urban heat islands will diminish the quality of life for residents by increasing the cost of living through higher electricity bills for air conditioning, increasing air pollution due to high demand of electricity, and through hotter days outside

Increase in heavy precipitation events will have direct impacts on the transportation system similar to sea level rise and increased storm surges. Increases in

heavy precipitation events will directly impact the FTP goals of agile, resilience and quality infrastructure, mobility, and transportation choice through network disruptions due to flooded facilities and crashes. An increase in precipitation events will directly affect safety and security due to faster deterioration of transportation facilities, especially roads, bridges, rails and runways, and an increase in weather-related traffic-related injuries and fatalities. Environmental stewardship will be directly impacted during heavy precipitation events because of increases in flash flooding and an increase in soil erosion and subsidence.

Heavy precipitation events cause temporary flooding in the area, which may have indirect impacts on economic competitiveness. Heavy rain events oftentimes result in less economic productivity in two major employment sectors – tourism and agriculture. Usual high-traffic areas for tourism in Florida, like the beach, are mostly empty during rainy days. An increase in rainy days may result in a decrease in tourism for those who currently travel to Florida, and consequently a reduction in tourism spending. Similarly, heavy precipitation events can flood agriculture fields and reduce the value of Florida agricultural production. Thus, the increase in frequency and severity of heavy precipitation events would decrease Florida's economic competitiveness.

An increase in heavy precipitation events may also have cumulative impacts on the transportation system leading to decreased quality of life. The FTP goal of creating quality places may be impacted through an increase in traffic-related injuries and fatalities, nuisance flooding, and a more rapid deterioration of transportation facilities. Network disruptions due to road damage and flooded facilities would also cumulatively affect the efficiency and effectiveness of the transportation system.

Table 12. Impacts, Vulnerabilities, and Consequences Related to Environmental Changes						
		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Sea Level Rise and increased Storm Surges	Permanent inundation (flooding) of coastal areas due to rising sea levels. Increased periodic flooding in coastal areas from worsening storm surges and tidal "nuisance" flooding (not associated with storm surge);	Quality infrastructure Mobility Transportation Choice Safety and Security Environmental Stewardship	Economic Competitiveness	Quality Places	Low to moderate risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service due to flooded roadways.
Increasing Hurricane Intensity	Higher and more damaging storm surges and wave impacts. Increase in episodic temporary flooding. Need for emergency evacuations based on hurricane strength and predicted impacts. Hurricane force winds causing damage to property and infrastructure.	Quality infrastructure Mobility Transportation Choice Safety and Security Environmental Stewardship	Economic Competitiveness	Quality Places	Low to moderate risk in short term; high risk in mid-to-long term	Transportation network disruptions, loss of service, and loss of connectivity. Travel delays and canceled service (flight, rail, transit).
Temperature Increases	Longer periods of extreme heat (as measured in consecutive days over a certain temperature).	Quality infrastructure Mobility Transportation Choice Safety and Security Environmental Stewardship	Economic Competitiveness	Quality Places	Low risk in short term; moderate to high risk in mid-to-long term	Network disruptions due to road damage, construction and maintenance delays. Potential for the creation of urban heat islands

Table 12. Impacts, Vulnerabilities, and Consequences Related to Environmental Changes (continued)						
		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Increase in heavy precipitation events	Increase in flash flooding. Increase in soil erosion and subsidence. Changes and fluctuations to the existing floodplain.	Quality infrastructure Mobility Transportation Choice Safety and Security Environmental Stewardship	Economic Competitiveness	Quality Places	Low risk in short term; moderate to high risk in mid-to-long term	Network disruptions due to flooding and crashes. Faster deterioration of infrastructure. Increase in traffic-related injuries and fatalities.

Interaction with Potential Future FTP Scenarios

The four environmental areas of concern are heavily related to the Return to Historic Growth scenario of the FTP, especially with sea level rise and increased storm surges (Table 13). The Return to Historic Growth scenario assumes that population growth continues according to historic rates of about 800 people per day, and that urban and suburban places near cities will continue to develop at current rates. Considering the scenario, an increase in population in existing urban centers would create greater demand on the transportation system due to increasing density and development. Many of Florida's existing urban centers, such as Miami, Ft. Lauderdale, Jacksonville and Tampa, are in the coastal zone. With sea level rise and increasing storm surges having greater risks in the coastal zone, an increase in population or the rate of population growth would result in various consequence. One of the main consequences of the risks associated with sea level rise are the impacts to the population, tourism, and economy due to permanent flooding. Permanent flooding from sea level rise will inhibit further

development in the coastal zone by completely inundating coastal neighborhoods and other land uses, thus impacting local economies and tourism. Other consequences include restriction of new development to areas with higher elevation protected from sea level rise or prohibition of development in the coastal zone altogether. To address and mitigate these risks, various sea level rise adaptation strategies exist, including protection, accommodation, and retreat (Lee, 2014; Nicholls, 2011).

Similarly, under the Return to Historic Growth scenario, increased hurricane activity will result in other uncertainties leading to risk. The uncertainties in this scenario include an increase in the population, an economy focused on tourism and construction, and motor vehicles remaining the primary mode of travel. As mentioned earlier, an increase in population in Florida's existing urban centers along the coast would result in larger impacts to coastal areas and coastal infrastructure; in relation to increased hurricane intensity, there would be greater detriments to the economy, population, and tourism through flooding, the cost of hurricanes, and evacuation. Additionally, the evacuation of larger populations under this scenario would create issues with mobility and connectivity for roadways and flights during evacuation. The reliance on motor vehicles may also create more stress on highways and roadways in the event of a hurricane, where gridlock and crashes are commonplace.

The other two environmental areas of concern, temperature increases and an increase in heavy precipitation events, have similar uncertainties leading to risks as the first two environmental areas of concern under the Return to Historic Growth scenario; however, their consequences differ slightly. The two uncertainties leading to risks that relate to temperature increases and an increase in heavy precipitation events are the

increase in population in existing urban centers and the reliance on traditional motor vehicles. For temperature increases, the consequences of an increase in population would be more energy users, who would exacerbate the urban heat island effect; this would result in further deterioration of urban transportation infrastructure including roadways, bridges, rail lines, and runways (Jacobs et al., 2018). Additionally, the reliance on traditional motor vehicles would result in more wear-and-tear on the roads, leading to more construction and maintenance, and transportation network delays. With increases in heavy precipitation events, the consequences would be an increase in congestion due to temporary flooding, and network disruptions and delays in construction and maintenance as a result.

The Rural Rediscovery scenario assumes that rural areas could see population and development growth due to changes in technology, revitalization of the agricultural sector, and demands for inland land and locally sourced food. In terms of sea level rise and increased storm surges, the precedence for an increase in development and population in rural areas may stem from costs and concerns about coastal flooding, encouraging residents to move to inland Florida. The abandonment of coastal property and infrastructure to inland areas, which are mostly rural, would create a shift in Florida's geospatial distribution of the population. The consequence for this uncertainty and risk is the potential for additional population at higher density in rural areas from climate refugees and new development, which in turn, put stress on low-density, rural transportation systems. There may be further issues with congestion, connectivity, and mobility if the density in rural areas could not handle the influx of new residents and economic growth. Other consequences may arise with this scenario as well, including

the relocation of critical coastal infrastructure, like seaports to areas unaffected by sea level rise and permanent flooding, as well as building new infrastructure to compensate for the losses incurred from sea level rise.

Under the Rural Rediscovery scenario, in the event of a hurricane, there would be more stress on rural transportations systems during emergency evacuation due to the increased population and development. Additionally, there would be a loss of connectivity between urban and rural areas during hurricanes, thus restricting economic activity, communication, and mobility for the duration of the hurricane. One of the most impactful consequences may be the economic costs of hurricanes, including damage to roads and rail lines, debris, and economic losses and resource depletion from evacuation.

When considering an increase in temperature due to climate change, specifically global warming, there will be general consequences with the degradation of rural transportation infrastructure, including softening of pavement, bridge scouring, and rail expansion. In contrast to urban areas, there would not be an exacerbation of heat island effect since this scenario focuses on an increase in rural development; however, there may be a possibility that a rapid increase in rural development, population, and overall energy usage would result in the creation of new heat islands. Additionally, rising temperatures may affect agricultural crop health, as some crop species may not perform as well in hotter temperatures, thus affecting export amounts and usage of rural-to-urban transportation systems, like freight and rail. Hotter days may also delay construction and maintenance of rural infrastructure, and production of agricultural products.

An increase in heavy precipitation events in rural areas would result in greater soil degradation and changes to the soil composition, in addition to the soil changes from new development and construction (USGCRP, 2018). This has further consequences on agriculture and rural transportation infrastructure through changes in soil drainage, subsidence, and an overall deterioration of roadways and rails. Similarly, there may be delays in rural transportation systems based on their ability to handle temporary flooding. These delays would be exacerbated by the increase in population for rural areas, thus resulting in network disruptions and the potential for congestion from temporary flooding.

The Global Trade Hub scenario focuses on Florida's potential future having significant expansion in global trade, tourism, and investment. The most influential uncertainty leading to risk in this scenario is the growth of economic development in existing urban centers. Many of Florida's existing urban centers are within the coastal zone; additionally, seaports and airports are critical infrastructure that are at high vulnerability to sea level rise and increased storm surges. Overall, sea level rise and increased storm surges would hinder expansions in global trade, tourism, and investment due to inundation of seaports and airports, thus limiting imports and exports. There may be a need to protect, accommodate, or relocate critical infrastructure like seaports and airports to other areas in order to satisfy the Global Trade Hub scenario. In addition, there will be consequences to tourism considering coastal erosion and dune losses on popular beaches, as there may be a need for more investment in dune protection or beach nourishment to protect beaches since they are a major venue for tourism.

Hurricanes and other natural disasters are known for halting economic activity, due to evacuations, congestion, damages, the cost of hurricanes and rebuilding, and flooding. With increased hurricane intensity, there will be consequences related to coastal areas and transportation infrastructure, causing greater detriments to the population, visitors, and the economy. Additionally, there will be a heavy disruption of mobility and connectivity of goods and services during and after hurricane events. Overall, the Global Trade Hub scenario is incompatible with increased hurricane intensity since economic activity, connectivity, and mobility are all impacted during hurricane events.

The last two environmental areas of concern, temperature increases and an increase in heavy precipitation events, have similar uncertainties leading to risks under the Global Trade Hub scenario. In terms of temperature increases, there is uncertainty leading to risk in the improvement of rail and road connections to major airports and seaports to support a trade-centric economy. The consequences of this would be disruptions in the transportation system due to temperature-related maintenance and construction delays, specifically where increasing temperatures would cause softening of pavement and rail expansion, thus increasing the need for maintenance and construction. In addition, heatwaves limit the amount of maintenance and construction that workers can complete, since hotter temperatures leave workers more fatigued and less productive. Overall, this delay with maintenance and construction would slow the movement of goods and services under the Global Trade Hub scenario. Similarly, increases in heavy precipitation events has uncertainties related to risks to economic development in existing urban areas. Since many of Florida's existing urban areas are

located in the coastal zone, network disruptions due to temporary flooding caused by the increase in heavy precipitation events will have consequences. Temporary flooding can cause delays in the movement of goods in services as well, since critical transportation infrastructure and facilities, like roadways, seaports, and airports, would become flooded.

The Innovation Hub scenario entails an emphasis on technology and innovation, particularly in urban centers. Again, there is a sense of economic growth and more skilled workers entering the labor force, though it is framed in terms of innovation in cities with new transportation technology. With the Innovation Hub scenario, a common uncertainty leading to risk in terms of the environmental areas of concern is the multi-modal approach to transportation, including walking, bicycling, shared vehicles, streetcars, and an integrated approach to delivery of goods and other freight. Similarly, in the Innovation Hub scenario, the expansion of current infrastructure in urban areas to accommodate more people and a growing economy. The consequence of this is the high vulnerability of innovation hubs to sea level rise and increased storm surges, since many existing urban centers are located along the coast. Another consequence is temporary flooding from sea level rise, which causes congestion and delays in the transportation system and affects all modes of transportation, including walkability, bicycling, and vehicular traffic.

Under the Innovation Hub scenario, the uncertainty leading to risk regarding sea level rise and increased storm surges is that economic growth will transform urban centers, many of which are along the coast. Again, the consequences of focused development in urban centers is that urban centers are highly vulnerable to increased

hurricane intensity and its impacts, such as temporary and permanent flooding, wind damage and debris, and evacuations. During and after hurricanes, cities will encounter economic losses, including the costs of hurricanes and damages.

Under the Innovation Hub scenario, the uncertainties leading to risks regarding temperature increases include the usage of multi-modal transportation systems and younger, skilled workers choosing Florida for its economic prosperity and employment options, thus increasing the population's working class. The consequences of this are a decrease in the quality of life for the growing population, due to higher energy costs and exacerbation of urban heat island effect. There may be opportunities under the Innovation Hub scenario to adapt to increasing temperatures, since new development can include vegetation and using green building principles to mitigate the temperature increases and reduce energy consumption. Overall, there is an opportunity to use innovative technologies under this scenario to offset the transportation system's carbon footprint.

The multi-modal approach to transportation, including walkability, bicycling, motor vehicles, public transportation, streetcars, and other forms, would have consequences to the transportation system and its users when considering an increase in heavy precipitation events. Mainly, the temporary flooding caused by an increase in heavy precipitation events would affect all modes of transportation through congestion and network delays; this would overall reduce connectivity between urban centers, and within them. The increase in heavy precipitation events may also lead to more weather-related crashes, thus putting all road-users at risk.

The final scenario from the FTP, Risks on the Horizon, outlines the potential risks to Florida's transportation system through a variety of uncertainties leading to risks, including population decline, a diminishing economic sector, extreme climatic changes, and more. Each of the environmental areas of concern are interconnected under the Risks on the Horizon scenario. For example, the combination of sea level rise and increased storm surges, and the increase in hurricane intensity, will create larger issues for the state's transportation infrastructure when considering the devastating impacts of flooding. Other connections include temperature increases exacerbating sea level rise and increased storm surges, the increase in heavy precipitation events and temperature increases both causing network delays and construction and maintenance delays, and the issue of temporary flooding with more rain events with hurricane flooding. The environmental areas of concern are the amalgamation of the Risks on the Horizon scenario. The following sections further discuss the uncertainties leading to risks under the Risks on the Horizon scenario, and the environmental areas of concern that have a role in defining the consequences.

With sea level rise and increasing storm surges, there is uncertainty leading to risks related to the Risks on the Horizon scenario. The uncertainty related to climate trends, like temperature changes and how fast and devastating sea level rise will affect Florida, is an uncertainty leading to risk. This creates consequences for Florida's transportation system, including loss of land and coastal infrastructure due to sea level rise and permanent flooding. There may also be consequences related to people moving inland from the inundation of coastal property, and the loss of important urban economic centers along the coast. Additionally, critical infrastructure like seaports,

airports, and roadways will all be impacted depending on the depth of sea level rise. This would have cascading consequences on mobility, the transportation of goods and services, and the quality of the infrastructure. Overall, sea level rise and increased storm surge contributes high risk to the Risks on the Horizon scenario and has a range of consequences for Florida's transportation system.

Increases in hurricane intensity has uncertainty leading to risks under the Risks on the Horizon scenario considering the frequency of hurricanes and storm events. The ability for the current transportation system to handle an increase in hurricane intensity creates uncertainty that leads to future risks. The consequences of this are the loss of mobility and connectivity during hurricane events, where economic activity and the movement of goods and services is stopped or delayed. Other consequences include economic costs of hurricanes from damages and a loss of economic productivity, and further consequences to population and development.

For temperature increases, the uncertainty leading to risks under the Risks on the Horizon scenario is the possibility of slowed population growth. With this uncertainty, the migration of workers or retirees to Florida from other states is reduced, thus reducing Florida's economic competitiveness and possibly slowing economic growth. Regarding temperature increases, there may be consequences related to the decrease in incoming population with a stagnation or even reduction in the urban heat island effect. Under this scenario, since there would be less people migrating to Florida from other states, there may be less energy usage and consumption in urban areas, thus stalling the exacerbation of urban heat island effect from an increase in temperature.

With an increase in heavy precipitation events, the uncertainties leading to risk under the Risks on the Horizon scenario are the changes in climatic patterns and the adaptability of the transportation system to temporary flooding. The consequences range from the loss of connectivity due to permanent flooding and network disruptions from an increase in heavy precipitation events. In addition, there may be structural degradation of transportation infrastructure due to subsidence, changes in soil composition, and drainage issues.

Table 13. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in the Environment

Scenarios from FTP	Areas of Concern	Uncertainty Leading to Risk (Based on FTP Vision Element)	Consequences of the Risks
Return to Historic Growth	Sea Level Rise and Increased Storm Surge	Increase in population in existing urban centers Greater demand on the transportation system	Restriction on new development to areas protected from sea level rise Protection, accommodation or retreat
	Increased Hurricane Intensity	Increase in population to the state Motor vehicles remain the primary mode of travel	Coastal areas/coastal infrastructure and greater detriments to population, visitors, and the economy Evacuation of larger populations during hurricanes
	Temperature Increases	Increase in population in existing urban centers More stress and demand on the transportation system Heavy reliance on traditional motor vehicles	Exacerbation of urban heat island effect given high growth in population and more visitors using more energy; Further deterioration of transportation infrastructure in urban areas More maintenance and construction
	Increases in heavy precipitation events	Population and economic growth in existing urban areas Motor vehicles remain the primary mode of travel	Increase congestion related to temporary flooding Network disruptions and delays in construction and maintenance

Table 13. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in the Environment (continued)			
Scenarios from FTP	**Areas of Concern**	**Uncertainty Leading to Risk (Based on FTP Vision Element)**	**Consequences of the Risks**
Rural Rediscovery Rural Rediscovery	Sea Level Rise and Increased Storm Surges	Costs and concerns about coastal flooding encouraging residents to move to inland Florida	Potential for higher density in rural areas from climate refugees and new development
	Increased Hurricane Intensity	Increasing and expanding population into rural areas Expanding Florida's agricultural sector and connections between rural and urban areas	More strain on rural transportation systems during hurricane evacuations Loss of connectivity between rural and urban areas during hurricanes Economic costs of hurricanes to rural transportation systems
	Temperature Increases	Population and economic growth in rural areas Expansion of agricultural production in rural areas	Degradation of rural transportation infrastructure through softening/expansion of pavement, bridge scouring, and rail expansion Delay in maintenance, construction, and production in rural areas
	Increases in heavy precipitation events	Florida's agricultural sector expands Population growth in rural areas	Greater soil degradation and changing soil composition in rural areas Delays in transportation systems
Global Trade Hub	Sea Level Rise and Increased Storm Surges	Seaports and airports become leading gateways for imports and exports Focus on economic development in existing urban areas, many in the coastal zone	Sea level rise hindering expansions in global trade, tourism, and investment due to impacts on airports and seaports Coastal erosion impacting high-traffic beaches More investment in beach nourishment
	Increased Hurricane Intensity	Critical trade infrastructure, like seaports and airports, being the main driver for economic development	Larger impacts to coastal areas/coastal infrastructure Congestion, and debris Critical trade infrastructure impacted Disruption of mobility and connectivity of goods and services during hurricane events
	Temperature Increases	Improve rail and road connections to major airports and seaports	Disruptions in the transportation system through temperature-related maintenance and construction delays
	Increases in heavy precipitation events	Focus on economic development in existing urban areas, many in the coastal zone	Network disruptions due to temporary flooding would slow the flow of goods and services related to trade

Table 13. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in the Environment (continued)			
Scenarios from FTP	**Areas of Concern**	**Uncertainty Leading to Risk (Based on FTP Vision Element)**	**Consequences of the Risks**
Innovation Hub	Sea Level Rise and Increased Storm Surges	Expansion of current infrastructure in urban areas to accommodate more people and growing economy Multi-modal approach to transportation planning	High vulnerability of new innovation-hubs to sea level rise Temporary flooding, congestion, and delays in the transportation system impacting all modes of transportation
	Increased Hurricane Intensity	Economic growth transforming urban centers, many of which are within the coastal zone	Urban centers in the coastal zone are more vulnerable to increased hurricane intensity and its impacts Economic losses of coastal cities during and after hurricanes
	Temperature Increases	Multi-modal approach to transportation, including bicycling, walking, shared vehicles, streetcars, and more Younger, skilled workers choosing Florida for its economic growth and prosperity; increase in working class	Decrease in the quality of life for growing population; Higher energy costs Using vegetation and green buildings to mitigation using vegetation and green buildings
	Increases in heavy precipitation events	Multi-modal approach to transportation, including bicycling, walking, shared vehicles, streetcars, and more	Temporary flooding, congestion, and delays in the transportation system Reduced connectivity between urban centers, and within them
Risks on the Horizon	Sea Level Rise and Increased Storm Surges	Uncertainty pertaining to climate trends relative to sea level rise, in addition to temporal changes, creates future risks	Loss of land and infrastructure in the coastal zone Permanent flooding impacts critical infrastructure, mobility, quality of infrastructure, population, and economy
	Increased Hurricane Intensity	Frequency of hurricanes and storm events; ability for transportation system to address hurricanes and evacuation	Loss of mobility during hurricane events on all modes of transportation; economic losses from hurricane costs and damages
	Temperature Increases	Slowed population growth; migration of workers or retirees to Florida from other states is reduced	Reduction in urban heat island effect with slowed population; possibly resulting in stagnant temperatures based on energy consumption
	Increases in heavy precipitation events	Changes in climatic patterns; adaptability of coastal infrastructure to temporary flooding	Loss of connectivity due to temporary flooding; structural degradation of infrastructure due to subsidence, changes in soil composition, and drainage

Table 14 summarizes the likelihood, frequency, vulnerability, threshold, and consequences regarding environmental risks. The likelihoods for both sea level rise and

network disruptions are expected due to exacerbation of climate change and climate change impacts. The risk of deterioration of the structural integrity of infrastructure is likely due to various environmental impacts including scouring of bridge supports from heavy precipitation, buckling of rail lines from extreme heat, road inundation and deterioration from sea level rise and flooding, and others. For increased hurricane intensity, heavy precipitation events, temperature increases, and interdependency of critical infrastructure, the likelihood is probable. As for the frequency of environmental risks, network disruptions, increasing hurricane intensity, and heavy precipitation events are all ongoing since these risks are currently impacting the transportation network. Sea level rise, structural integrity of infrastructure, temperature increases, and interdependency of critical infrastructure are all long-term risks that will impact Florida's transportation network. Sea level rise may have a local threshold based on the coastal city and local vulnerability assessments. This local threshold differs from one area to another based on elevation and existing infrastructure, such as sea walls and raised roads. While sea level rise is a gradual change that is hard to designate a threshold or tipping point at the state level, thresholds may exist at the local level based on geographic characteristics and level of vulnerability. While both vulnerabilities and consequences are discussed in other sections, it should be noted that sea level rise, increasing hurricane intensity, heavy precipitation events, and interdependency of critical infrastructure have extreme consequences to the transportation network.

Table 14. Environment Risk Matrix					
Risk	Likelihood	Frequency	Vulnerability	Threshold	Consequences
Network Disruptions	Expected	Ongoing	High	No	Moderate
Sea Level Rise	Expected	Long term	High	No	Extreme
Structural Integrity of Infrastructure	Likely	Long term	Low	No	Moderate
Increased Hurricane Intensity	Probable	Ongoing	High	No	Extreme
Heavy Precipitation Events	Probable	Ongoing	Moderate	No	Extreme
Temperature Increases	Probable	Long term	Moderate	No	Minor
Interdependency of Critical Infrastructure	Probable	Long term	Moderate	No	Extreme

Technology Risks

One of the most pressing risks stemming from technological advancements in transportation are the associated changes in travel behavior. This risk is directly connected to another, data generation and access, that is associated with the introduction of increasingly advanced transportation technologies. These two risks will arise in concert with each other through the implementation of technologies, such as advanced infotainment systems and higher levels of vehicle autonomy and connectivity. The connection between these two risks is evident through the influence that access to data generated by transportation technologies will have in understanding any elicited changes in travel behavior. The associated consequences of these risks can lead to the misallocation of investments as well as misdirected initiatives, policies, and employment opportunities, among others. For example, without knowing the number of ridesharing drivers on the road at a given time, number of ridesharing users, and frequency of trips taken via this mode, the level of traffic could rise, stay the same, or decline in travel by automobile that could lead to an over or under investment in roadway infrastructure. Additionally, investments in new technologies are expensive and they need to be coordinated with each other to ensure system reliability and stability, while avoiding unnecessary expenditure on obsolete or incompatible infrastructure for both communications and vehicle right-of-way.

Autonomous and connected vehicles are also considered to impose risks for the transportation system. One of the most pertinent risks stemming from the transition to autonomy and connectivity is that there will be transitional phases where the mix of technology and vehicles will create a more complex system. Full autonomy is expected

to reduce or remove all human error from the transportation system. However, the transitional phases leading up to full autonomy may have adverse implications for the safety of the transportation system. For instance, the deployment of truck platooning is expected to be one of the first initiatives to be implemented.

While truck platooning will result in the more efficient distribution of goods across the state and may reduce human error from the trucking industry, any incident involving a trucking platoon will likely result in more-devastating crash incidences. Moreover, if one vehicle is not operating through a fully automated and connected network (i.e. human driver), the entire system is at risk because of the errors, inefficiencies, and other negative externalities stemming from its operation. Human driver behavior in light of the presence of AVs is also a potential cause for concern. In California, there are already issues arising through the interactions of human operated vehicles and AVs, with humans being more aggressive towards their AV counterparts (Eliot, 2019). These instances have led to questions over whether the “bullying” of AVs by human drivers should be unlawful or part of the transition towards automation (Eliot, 2019). It has also called to question typical driving tactics of aggressive drivers towards passive drivers and the implications the two different approaches to driving will have on the culture and utility of AVs. These issues will be more profound if AVs are deployed at a large scale prior to the development of adequate vehicle-to-vehicle (V2V) connectivity.

Because they involve a diverse set of technologies, autonomous and connected vehicles will most likely follow the 10 x 10 rule of inception and adoption; they may take ten years to develop and ten years for widespread adoption. While autonomous and connected vehicles are physical assets that incorporate software elements, other

transportation technologies and telecommunications are software assets that require a physical element. As such, the adoption and mass diffusion of these technologies follows closer to the one by one rule of inception and adoption, especially due to their web-based functionality. Therefore, it is more likely that other transportation technologies and telecommunications will more drastically alter travel behaviors and mode choice in the short term compared to AVs and connected vehicles (CVs). In fact, the adoption rate of these technologies may enable the government to proactively prepare for the mass deployment of autonomous and connected vehicles through policy and partnerships.

In addition to the data sharing and compatibility issues mentioned above, other risks, such as the compatibility of future energy choices with the current infrastructure and energy supply, must be addressed in the next update of the FTP. For example, EVs are being sold at historic rates and hybrid vehicles are facilitating the change from gas to electric energy choices in transportation. While EVs are having an increasing ability to travel longer distances on a single charge, a transition to EVs will require substantial changes to the current transportation energy infrastructure, including fueling stations. In addition to the locational supply of energy for EVs, the ability of the electric grid to sustain the charging of massive numbers of EVs is another concern for the future energy choices of the transportation system. As such, varying levels of uncertainty and vulnerability (i.e. adoption rates) leads to risks within the area of concern of advancing transportation technologies, as shown in Table 15. The sharing economy's long-term effect on the transportation system is still uncertain (Table 15), yet the shared economy is changing the transportation options available to passengers and the associated travel

behavior. One example is through shared-autonomous vehicles (SAVs), which would have the most direct effect on passenger transportation and could be beneficial to public and intercity transportation by offering transportation choice to travelers (Heinrichs, 2016).

Table 15. Uncertainties Leading to Risk in the Transportation System Related to Technology

Area of Concern	Potential Uncertainty	Potential Vulnerabilities	Assets Affected	Level of Vulner-ability	Consequences of Each Type of Uncertainty	Risk
Sharing Economy	Rate of adoption, cost-effectiveness, impact on other modes, especially, transit connectivity, pricing out of services, Private vs. public role Cost	Impacts on congestion and VMT	Potential increase in the need for roadways Market share of the transportation sector, jobs, economy, mobility All types of transit	Moderate in the short term; high in mid-to-long term	Expansion of travel choices and changes in demand for various modes Changing Employment Opportunities	Changes in VMT and congestion Cost of travel could fluctuate Ride-sharing effect on public transit Changes in the logistics industry
Autono-mous and Connected Vehicles	Adoption, inter-connection of public and private operations, Level of autonomy.	Increasing connectivity of smartphones and automobiles can cause safety and liability concerns. High interlinkage or interdependency between public and private infrastructure and operations; increase in congestion and VMT	Potential increase in the need for roadways Market share of the transportation sector, Jobs, Economy, Mobility, Other modes of transit	Moderate in the short term; high in mid-to-long term	Change in Demand for Automobiles, Trucks, Change in Mode Choice;	Compatibility of current infrastructure Public Private Relationship (logistics+ data sharing) Mixing autonomous and regular vehicles Adoption of telecommunica-tions technology

Table 15. Uncertainties Leading to Risk in the Transportation System Related to Technology (continued)						
Area of Concern	**Potential Uncertainty**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of Each Type of Uncertainty**	**Risk**
Other Transportation Technologies and telecommunications	Role of the public sector related to private sector transportation regulation	Greater interconnections between transportation and other systems (e.g., communications) Change in the role of the public sector	Existing transportation infrastructure	Moderate in the short term; High in the mid-to-long term	Expanded mobility and connection options Change in activity pattern Changes in flexibility and reliability Changes in Infrastructure	Challenges related to implementing app technology to improve local and intercity travel Institutional structures required to implement technology like V2V and V2I communication
Energy Choice	The rate of adoption of non-fossil fuel sources	Pricing of oil in global context Substitutability of other fuels	All modes of travel; potentially some more than others (ports, airports); impact on the overall economy	Low risk in the short term; high risk in mid-to-long term	Change in vehicle energy source technology Change in fuel stations Compatibility with transportation infrastructure Geopolitical arrangements	Infrastructure to support transitional fuel vehicles Design and function Cost of retrofitting existing vehicles and infrastructure

Interaction with FTP Goals

The sharing economy directly affects five goal areas of the FTP: mobility, transportation choice, quality infrastructure, safety and security, and economic competitiveness (Table 16). The establishment of the sharing economy in transportation is most notably associated with the introduction of on-demand, ride-hailing and ridesharing service providers, often referred to as transportation network companies (TNCs), specifically like that of Uber's 2009 inauguration. These services directly affect mobility and transportation choices by providing additional mobility options for the state

that are especially influential for the non-driving segments of the population excluded from traditional transit services.

While the establishment of ride-hailing and ridesharing services as viable modes of transportation provides new mobility options, there is a geographical concentration of these services, with most being available in only urban and suburban areas, leaving rural areas largely unserved (Ralph, 2017; Smith, 2015).

While the sharing economy provides new mobility options, it has the potential to directly impact the FTP goal of quality infrastructure through its directional relationship with VMT and congestion, as well as changing preferences in mode choice. Depending on the direction of this relationship there may be either an expansion or contraction in maintenance activities, due to added wear and tear on the road infrastructure or a reduced need for these activities through reduced VMT and congestion. The transportation sector of the sharing economy will also have direct impacts on the safety and security of the transportation system and cumulative impacts on environmental stewardship, which are similarly dictated by the directional relationship these models have with VMT and congestion.

The sharing economy will indirectly affect creation of quality places through the mobility and transportation choice implications of ride-hailing and ridesharing services in regards to car dependency and equitable service accessibility. In addition to car dependency and equitable accessibility, the sharing economy will also impact the creation of quality places through its effect on economic competitiveness and safety and security. Job creation in the transportation sector through the sharing economy will improve the opportunity to create a quality place by providing additional transportation

options for users and flexibility in work schedules for driver-partners. The consequences stemming from the sharing economy focus on the expansion of travel choices and employment opportunities, as well as the ensuing changes in demand for various modes of transportation and their impacts on VMT and congestion.

AVs, CVs, and CAVs will directly impact mobility, transportation choice, safety and security, and economic competitiveness (Table 16). These impacts will vary and intensify in accordance with the level of autonomy of the transportation system. Any introduction of autonomy will drastically alter the mobility and transportation choices of residents. AVs will improve the mobility for non-licensed citizens, specifically for demographic groups like that of the youth and non-driving older adults, as well as the impoverished (Litman, 2018).

Safety and security of the transportation system will drastically change with the deployment of AVs, CVs, and CAVs. As discussed later in the section on cyber security below, autonomy and any technology connecting vehicles exposes the transportation system to cyber-attacks that could partially to totally disrupt transportation activities. Aside from the increasing vulnerability to cyber-attacks, automation will affect safety and security during the transition through different levels of autonomy (i.e., non-autonomous, partially-autonomous, and fully-autonomous).

Automation and connectivity of driving are projected to have a societal value of $1 trillion (WEF & Accenture, 2016a), while also contributing to a creation of two million jobs in logistics over the next ten years (WEF & Accenture, 2016b), many of which will be affiliated with transportation services and operations. Thus, the introduction of AVs, CVs, and CAVs has the potential to directly affect economic competitiveness through

stimulating positive shifts of demand and supply curves spawned through economies of scale, new markets, and new products and services (Mudge, 2018). Additionally, AVs, CVs, and CAVs can further impact economic competitiveness through improving access to jobs, markets, intermediate goods and raw materials (Mudge, 2018).

AV, CVs, and CAVs indirectly impact the FTP goals for quality places and quality infrastructure. As mentioned above, acceptance and adoption of these vehicles remains uncertain with autonomous vehicles expected to be expensive and not affordable for all for the foreseeable future (Sayer, 2018). As such, the transition towards autonomy will be slow, due to the initial costs of new vehicles (Litman, 2018; Meeting 5). Therefore, autonomous vehicles will indirectly impact the creation of quality places through the temporal lag in adoption. AVs, CVs, and CAVs cumulatively impact environmental stewardship in the same manner as the sharing economy, which is through the impacts of AVs and SAVs on congestion and VMT and with electricity and other alternative fuels. The consequences of transitioning to AVs, CVs and the more advanced CAVs derives from the changing demands and preferences for various modes of transportation and their impacts on VMT and congestion, and the changing employment opportunities in parts of the transportation sector. AVs and CVs will provide additional modes of transportation for the state's population. However, the availability of these additional modes will alter demands for traditional transportation choices and levels of individual automobile ownership.

Other transportation technologies directly affect mobility, transportation choice, quality of infrastructure, quality of place, and economic competitiveness within the state (Table 16). Infotainment systems have the potential to negatively impact mobility

through enhancing the commuting experience. However, infotainment systems can improve mobility and reduce VMT and congestion through intelligent route guidance, congestion avoidance and data sharing from the V2V and the vehicle-to-infrastructure (V2I) connectivity. Multimodal integration will have similar impacts on mobility through increasing the connectivity between various transportation modes, offering additional transportation choice and expanding the data sharing process of the transportation sector. The shared characteristics of these two transportation technologies will have simultaneous and compounded impacts on mobility and transportation choice by enhancing the optimization of the transportation system.

Other transportation technologies directly impact the quality of transportation infrastructure through the progression towards increasing the connectivity of vehicles to each other and with the transportation infrastructure. The increasing trend of telecommunications and e-commerce activity will also directly impact the quality of transportation infrastructure. Other transportation related technologies will directly affect safety and security of the system and its users. Infotainment systems have the potential to improve the safety of users through intelligent navigation and congestion avoidance. Moreover, technologies such as, infotainment systems and multimodal integration, directly impact economic competitiveness. The increasing connectivity of vehicles to other vehicles and transportation infrastructure through advancing infotainment systems is increasing the efficiency and further optimizing the transportation system, specifically regarding the movement of goods, services, and human capital.

Other transportation technologies, such as multimodal integration and advanced infotainment systems, cumulatively affect environmental stewardship by promoting more

efficient traffic management, reducing congestion, and promoting eco-friendlier transportation behaviors (WEF & Accenture, 2016a). The consequences stemming from other transportation technologies, telecommunications, and e-commerce influence changes in activity patterns, the flexibility and reliability of transportation options, and the quality of infrastructure. Infotainment systems have the potential to improve or worsen traffic and congestion issues through the impacts on commuter experiences and the ability to provide intelligent navigation.

Changes in energy choice for the transportation sector, and the associated vehicle technology, are likely to have a direct impact on the FTP goals of quality infrastructure, economic competitiveness, transportation choice, and environmental stewardship (Table 16). From an economic competitiveness perspective, Florida can increase it energy production from a variety of sources, including solar, wind and biomass that use local sources of energy.

The change in fuel choice indirectly affects mobility, and safety and security and cumulatively affects the goal of quality places. Depending upon the details associated with vehicle type and the associated infrastructure, the mobility and transportation choice could improve or worsen. A shortage of fuel/recharging stations could reduce mobility of the traveling public using new fuel vehicles. At the same time, mobility could be improved if the changes in fuel type is accompanied by additional shared autonomy options. The safety and security of the traveling public during an energy transition can be improved, or worsened, depending upon how energy efficiency and fuel choices are implemented. Safety may be improved with a reduction in the amount of crude oil shipped into Florida ports. Cumulatively, the goal of creation of quality places would be

improved with greater energy choice due to improvements in local air quality, reduced GHG emissions, and increased consumer choice in vehicles. The consequences of changes in fuel choice are several including a change in vehicle technology and fuel stations, geopolitical arrangements and compatibility with the existing transportation infrastructure.

Table 16. Impacts, Vulnerabilities, and Consequences Related to Technology

		Impacts to Transportation System			Vulnerabilities and Consequences	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Sharing Economy	Ongoing; realignment of private sector User acceptability and adoption of sharing options	Quality infrastructure Mobility Transportation Choice Safety and Security Economic Competitiveness	Quality Places	Environmental Stewardship	Moderate in short term; high in mid-to-long term	Expansion of Travel Choices and Changes in Demand for Various Modes Changing Employment Opportunities
Autonomous and Connected Vehicles	Partial to total alteration of public and private transportation operations.	Mobility Transportation Choice Safety and Security Economic Competitiveness Quality infrastructure	Quality Places Quality infrastructure	Environmental Stewardship	Moderate in short term; high in mid-to-long term	Change in Demand for Automobiles, Trucks, Change in Mode Choice;

Table 16. Impacts, Vulnerabilities, and Consequences Related to Technology (continued)						
		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Other Transportation Technologies and telecommunications	Greater interconnections between transportation and other systems (e.g., communications); change in role of public sector	Mobility Transportation Choice Safety and Security Economic Competitiveness Quality infrastructure Quality Places		Environmental Stewardship	Moderate in short term; High in mid-to-long term	Expanded mobility and connection options Change in activity pattern Changes in flexibility and reliability Changes in Infrastructure
Energy Choice	Changes in vehicle type and design. Operational characteristics – range of vehicles and fuel infrastructure - of alternative fuels Environmental impact of fuel choices	Environmental Stewardship Economic Competitiveness Quality infrastructure Transportation Choice	Mobility Safety and Security	Quality Places	Low risk in short term; high risk in mid-to-long term	Change in vehicle energy source technology Change in fuel stations Compatibility with transportation infrastructure Geopolitical arrangements

Interaction with Potential Future FTP Scenarios

The scenario of a Return to Historic Growth would be that Florida continues to grow at a consistent growth rate of 800 people a day (FDOT, 2015b). In this scenario, development would continue in suburban and exurban places near cities and along major transportation corridors (FDOT, 2015b). An uncertainty related to returning to historic growth is the rate of adoption of AV, CV and CAV technology (Table 17). If the

adoption of autonomous vehicles is low or fails to happen, or if individual ownership is the dominant form of autonomous vehicle, a return to historic growth would lead to increased congestion on roadways in Florida (FDOT, 2015a). Autonomous and connected technology, if implemented in a timely manner, would reduce some of the negative parts of continuous growth, like increased congestion **(**WEF & Accenture, 2016a).

A scenario exists where rising energy costs could undermine Florida's return to historic growth (FDOT, 2015b). Low energy prices are beneficial to economic growth because they help keep transportation costs low (Sorensen, 2014). Tourism and trade benefit from low energy prices and get hurt if energy prices rapidly rise (Sorensen, 2014). Oil prices are generally expected to rise again and that could be triggered by a variety of events, such as geopolitical disruptions, outside of the control of a state DOT (Sorensen, 2014). Developing alternative financing sources to reduce our reliance on fossil fuels will become necessary to reduce that risk (Sorensen, 2014). Federal policies related to pricing carbon emissions, restricting vehicle emissions further, or increasing the federal gas tax would also increase the cost to travel, which could affect a return to historic growth scenario (Sorensen, 2014).

Rural Rediscovery could be impacted by how rapidly the implementation of CAVs happen. Many suburban and rural places lack the density to support conventional public transit (Polzin, 2018). AVs have the potential to increase assessability with affordable high-frequency transportation (Polzin, 2018). SAVs would be able to directly serve people without having to have a fixed route and can use existing road infrastructure (Polzin, 2018). SAVs have the potential to be cheaper than owning a

single occupancy vehicle, which makes living out in these suburban and rural places without a car possible (Polzin, 2018).

Telecommuting has the potential to make rural areas more attractive if better telecommunications infrastructure extends to rural areas. The benefit of telecommuting is that it removes a costly and lengthy commute that would be required to live outside of a city (Salmon, 2018). Employment would be separate from location so people could live where the cost is cheaper (Salmon, 2018). Working remotely could save a person up to 254.8 hours and thousands of dollars a year compared to commuting into Miami (Salmon, 2018). No matter what happens with telecommuting, higher paying jobs will continue to cluster in urban areas. Rural communities will continue to have a connection to nearby urban centers for both employment and goods and services. The rate of telecommuting will determine the strength of that connection.

The Global Trade Hub scenario focuses on expected growth for freight transportation and logistics in Florida, which will require investment in improving existing infrastructure. Since, the recession the logistics industry grew on average by 15% per year through 2014 (WEF & Accenture, 2016c). The rise of business to consumer (B2C) sector in the U.S. will lead to higher demand for freight transportation (WEF & Accenture, 2016c). Certain industries like the auto industry will be impacted because there is a push to remove the intermediary and go to direct sales instead of the existing dealership model (WEF & Accenture, 2016a). The B2C sector relies on reliable and fast freight shipping (WEF & Accenture, 2016c). Automation will have a negative impact on transportation employment since truck drivers will not be required (WEF & Accenture, 2016c). Employment would transition to focusing more on energy and

logistics, which is expected to grow by 6 million jobs globally by 2025 (WEF & Accenture, 2016b). The benefit of autonomous trucking is increased fuel efficiency, lower maintenance cost, and increased safety (WEF & Accenture, 2016c). Transportation fuel costs for freight in the future are another uncertainty that could lead to risk (Sorensen, 2014).

The scenario of an Innovation Hub focuses on a future where job and population growth is concentrated in cities (FDOT, 2015b). Florida would attract skilled labor that would live and work in cities (FDOT, 2015b). A focus urban growth could lead to challenges related to handling increased demand on our existing infrastructure. The adoption of CAVs will require cooperation between the public and private sector (WEF & Accenture, 2016a). Multimodal integration through an application will require public and private actors to cooperate on allowing customers to access a variety of modes (WEF & Accenture, 2016a). Multimodal Applications, like UbiGo, have been already been tested in Sweden, and represent opportunities for future integration into the transportation system (WEF & Accenture, 2016a). Multimodal integration if implemented would allow existing public and private transportation services and existing infrastructure to be used more effectively (WEF & Accenture, 2016a).

Urban freight would be in high demand in an Innovation Hub scenario. The challenge with urban freight is that, in dense cities, freight infrastructure can have a negative impact on the surrounding areas; transportation infrastructure is congested during the day, and space is a premium (WEF & Accenture, 2016c). Customers and companies are demanding high-priority, fast and reliable, freight service, which becomes a challenge with existing infrastructure (WEF & Accenture, 2016c). For local

deliveries, drones could be an alternative since they produce less pollution than a conventional van while avoiding crowded roads (WEF & Accenture, 2016c). At the same time, a significant expansion in the number of drones making deliveries would require policies, procedure and protocols.

The Risks on the Horizon scenario relates to the long-term challenges Florida could face. Some of these challenges include extreme weather events, recessions, and sea-level rise affecting our infrastructure (FDOT, 2015b). The risks on the horizon could affect any of the four non-risk-based scenarios (FDOT, 2015b). If multiple extreme weather events like hurricanes happen in a single year, it could damage our transportation, telecommunications and energy infrastructure (FDOT, 2015b). Transportation, like SAVs, would be unable to function if flooding or wind damaged the infrastructure that is required to operate (WEF & Accenture, 2016d). Rising energy costs could lead to another recession, which would have a negative impact on Florida's tourism industry (FDOT, 2015b). Digitalization of the economy could lead to massive changes in employment that could slow Florida's growth and slow the economy (WEF & Accenture, 2016d). Automation of vehicles and a move away from single-occupancy vehicle ownership could change employment in the automotive industry which could lead to job loses (WEF & Accenture, 2016a). Changes in fuel choice to electrification, whether to plug-in electric or to hydrogen-fuel cell will result in changes in employment and in a transportation system that is more connected to the electrical grid.

Table 17. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Technology

Scenarios from the FTP	**Areas of Concern**	**Uncertainty leading to risk**	**Consequences**
Return to Historic Growth	Autonomous and Connected Vehicles	Market Entry Adoption Rate Multimodal Integration	Changes in Congestion Urban land use Changes
	Energy Choice	Adoption of alternative fuels Fossil Fuel based transportation	Changes in demand for travel and mode choice
	Other Telecommunications and Transportation Technologies	Technology Changes Telecommuting	Reduced VMT from People Commuting Less
	Sharing Economy	The growth of TNCs	VMT Changing mobility trends Congestion
Rural Rediscovery	Autonomous and Connected Vehicles	The lack of autonomous ride-sharing vehicles could hurt the mobility of people living in rural areas	Accessibility to Ride Hailing Services Truck Platooning
	Energy Choice	Adoption of alternative energy Energy cost	Transportation cost Changes for people and freight
	Other Transportation Technologies and Telecommunications	Multimodal integration Telecommuting 3D printing	Lack of density challenges multimodal integration
	Sharing economy	Economics of TNCs	Changes in mobility and the cost of travel
Global Trade Hub	Autonomous and Connected Vehicles	Changes in Logistics Because of Automation Trucking Platooning	Reduced transportation employment Changes in supply chain efficiency
	Energy Choice	Fuel Costs	Cost to ship freight rises
	Other Transportation Technologies and telecommunications	Growth in Business to Consumer Sector	Reduction of VMT for traveling to stores but an increase in VMT for freight
	Sharing Economy	Importation of technology	Reliance on global economy to stay competitive

Table 17. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Technology (continued)			
Scenarios from the FTP	**Areas of Concern**	**Uncertainty leading to risk**	**Consequences**
Innovation Hub	Autonomous and Connected Vehicles	Continued privatization of transportation services Safety and efficiency benefits	Public sector role will change related transportation and infrastructure Changes in the utilization of our existing transportation network
	Energy Choice	Upgrading infrastructure to support the electrification of vehicles	Adoption of alternative fuels will lead to changes in the way people travel
	Other Transportation Technologies and telecommunications	Implementing 5G Technology Multimodal Integration Telecommuting	Institutional changes and resources required to implement improved wireless technology Connectivity between various modes of travel Change in commute patterns
	Sharing Economy	Automation of TNCs ride-hailing services	Reduced employment
Risks on Horizon	Autonomous and Connected Vehicles	VMT Public and Private Sector Relationship	Employment, mobility, and infrastructure
	Energy Choice	Transition to Electrification	Employment and infrastructure
	Other Transportation Technologies and telecommunications	Implementing technologies to support autonomy	Mobility and infrastructure
	Sharing Economy	Automation SAVs	Reduced employment

Table 18 summarizes the likelihood, frequency, vulnerability, threshold, and consequences regarding technology risks. Both ridesharing impacts and V2I Connectivity are expected to occur due to ongoing changes in technology. Conversely, the likelihood of autonomy, increasing role of the private sector, and energy choice compatibility are all likely considering the progression of technology. The likelihood for data sharing and V2V connectivity is probable, while fully CAVs is unlikely. Regarding frequency of technology risks, ridesharing impacts, increasing role of the private sector, and data sharing are ongoing risks. V2I connectivity, autonomy, and energy choice compatibility are risks in the near future depending on the rate of adoption and progression of technology. V2V Connectivity and fully CAVs are long term risks that

both have thresholds and extreme consequences. As for the thresholds of other technology risks, V2I connectivity, autonomy, and energy choice compatibility all have thresholds. Other extreme technology consequences include V2I connectivity, autonomy, increasing role of the private sector, and data sharing.

Table 18. Technology Risk Matrix					
Risk	Likelihood	Frequency	Vulnerability	Threshold	Consequences
Ridesharing Impacts	Expected	Ongoing	Moderate	No	Moderate
V2I Connectivity	Expected	Near Future	Moderate	Yes	Extreme
Autonomy	Likely	Near Future	High	Yes	Extreme
Increasing Role of Private Sector	Likely	Ongoing	High	No	Extreme
Energy Choice Compatibility	Likely	Near Future	High	Yes	Moderate
Data Sharing	Probable	Ongoing	High	No	Extreme
V2V Connectivity	Probable	Long term	Moderate	Yes	Extreme
Fully CAVs	Unlikely	Long term	Low	Yes	Extreme

Global Issues Including Security Risks

One of the most challenging relationships to define is between global issues, including security, and transportation infrastructure in Florida, yet the fiscal and operational stability of FDOT is connected with global events. Due to the success of the state, as the world's 19th wealthiest economy and a hub for international trade and tourism, Florida must find a method for analyzing what is vulnerable to a potentially unstable and even volatile relationship between the United States and other global powers. Other state and city governments have begun to create a framework for identifying actual risks and attempted to establish a system for protection and recovery from international disaster events. At the national level, global security is a constant challenge. Multiple federal initiatives currently focus on identification of threats, training for responders, and protective measures. FDOT should use the procedures from federal policies as a guide and look to find examples of what works from other U.S. governments who tackle the same general issues over trade and security.

In the early portion of this research, three main areas of risk posed by global issues were identified. The first, foreign relations - which includes political and trade stability - is intertwined with events at the national level of U.S. administration. Therefore, the precedent for activities and procedure that promotes or supports security against political fallouts has been set by federal agencies, such as the Transportation Security Agency (TSA), the U.S. Securities and Exchange Commission (SEC), and the Department of Homeland Security (USDHS).

The second area that is considered a main risk from global issues is vulnerability from cybersecurity. As described earlier in this project, the importance of cybersecurity in government is growing due to the increasing social dependence of emerging technology,

the possible mainstreaming of automation, and the danger in reliance on third parties for protection. Because cybersecurity is a rapidly advancing and independent field of expertise, integration of its practices into government operation is still developing. Yet, there are some examples of local government tackling challenges of cybersecurity, which will be outlined below.

The third area of risk and vulnerability identified by this group results from global social security and the influence of extremism. Once again, this area of risk has precedent in practices implemented by federal agencies. A number of national policies regarding security against terrorism have already become familiar in U.S. transportation. Florida might use these tested methods in its design of protective practice within the FDOT, but can alter its response based on what the state's infrastructure dictates. Due to the continuous globalization of the world, Florida is at risk to outside influences, such as external threats (cyber-attacks and terrorism) and the increasing significance of the global economy. Table 19 represents the varying levels of uncertainty and vulnerability, which lead to risks within the areas of concern pertaining to global issues.

Table 19. Uncertainties Leading to Risk in the Transportation System Related to Global Issues Including Security						
Area of Concern	**Potential Uncertainty**	**Potential Vulnerabilities**	**Assets Affected**	**Level of Vulnerability**	**Consequences of Each Type of Uncertainty**	**Risk**
Cyber Security	Cheaper and highly accessible technology	Increasing connectivity of smartphones and automobiles can cause safety and privacy concerns. High interlinkage or interdependency between public and private infrastructure and operations	Private and public property. For example, traffic control devices and management systems, power infrastructure, etc.	Moderately high risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service, and connectivity due to hacking Loss of economic efficiency Major threat to safety and security	Cyber Breaches (Vehicle/Infrastructure) Safety and Security of Transportation Network Increasing Data sharing and Connectivity Increasing access to technology worldwide
Terrorism	International conflicts, Extremism, Geopolitical tensions, Economic conditions	Technological advancements in wrong hands. Increasing mobility.	Economy, jobs and mobility	High risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service, and connectivity due to attack Impacts community livability through loss of life and injury Loss of economic efficiency Major threat to safety and security	Threat or Attack of Terrorism Increasing access to technology worldwide Implications of Globalization and the Global Economy
Global Economy	Geo-political landscape	Treaties, Tariffs, Trade Wars, Political Instability	Imports and Exports Associated transportation Facilities	Moderately High in short term; High in mid-to-long term	Changing trade activity Movement of Populations	Changes in importing and exporting goods Changes in migration patterns Changing trade relationships

Interactions with FTP Goals

Attacks on cybersecurity systems have the potential to lead to a partial to total shutdown of public and private transportation activities, this area of concern directly affects five goal areas of the FTP: quality infrastructure, mobility, transportation choice, safety and security, and economic competitiveness. Cyber vulnerability was deemed the biggest threat to transportation operations over a 10-year horizon in the 2016 Transportation Risk Index (Willis Towers Watson, 2016). As cyber-attacks are entirely targeted towards technology, this will alter the manner in which operations and maintenance activities are carried out. Specifically, the quality infrastructure goal of the FTP focuses on strengthening the cybersecurity of technology-based transportation infrastructure and equipment to prevent attacks. Mobility could be affected through the increasing connectivity between smartphones and various modes of transportation, where a disruption between these connections could negatively affect the ease with which destinations can be reached, resulting in decreased accessibility to certain areas. This situation is further exacerbated by the fact that safety and security will be increasingly more vulnerable in the face of a more technologically oriented transportation system, as automotive electronics are much easier to hack than computers, causing the notion of automation to be extremely volatile in the face of such attacks.

Changing patterns of mobility and any disruption in connectivity within and between modes will directly impact economic competitiveness (Table 20). While cyberterrorism does not necessarily deter travelers from a destination yet, this could be a very significant danger in the future through the automation of transit and transportation management systems. Once automation has experienced widespread

adoption and usage, the potential for cyber-attacks could significantly impact traveler's choice of destinations, as people choose to travel to places they deem safe.

Through the direct impacts on mobility, transportation choice, and safety and security of the transportation system, as well as the economic competitiveness of the state, cyber-attacks have the potential to indirectly affect the goal of quality places in a negative manner. The aforementioned direct effects associated with these goal areas would subsequently lower the overall quality of life by disrupting social stability through induced fear and potential distrust in transit systems. The consequences of any breaches in cyber security focus on the potential for transportation network disruptions and any ensuing threats to the safety and security of the network. Cyber security attacks, through hacking, have to potential to cause a partial to total shutdown of both public and private transportation operations. Any level of disruption would lead to a loss in logistical communications, mobility, services and connectivity, as well as increasing concerns surrounding the safety of the transportation system. These consequences magnify with the increasing reliance on technology in transportation services and operations.

While cyber security crosses an imaginary boundary, terrorism crosses physical boundaries to induce fear and disorder. Consequently, terrorism has direct impacts on safety and security, economic competitiveness, mobility, and transportation choice. More specifically, terrorism has the ability to deter travelers from specific destinations, due to safety issues. Any threat or act of terrorism will indirectly affect the FTP quality infrastructure goal through the need for heightened security measures for the transportation system. Threats and acts of terrorism will most likely lead to cumulative

impacts for environmental stewardship. Such threats could alter institutional and budget priorities away from environmental conservation, towards more development initiatives to improve safety measures, procedures and protocols. Similar to that of the consequences of any breaches in cyber security, the consequences stemming from any threat or act of terrorism centers around the potential for transportation network disruptions and major threats to the safety and security of transportation system users. Such disruptions would also lead to a loss of mobility, services, and connectivity, as well as increasing concerns surrounding the safety of the transportation system.

Table 20. Impacts, Vulnerabilities, and Consequences Related to Global issues including security

		Impacts to Transportation System			**Vulnerabilities and Consequences**	
Area of Concern	**Nature of Impacts**	**Direct**	**Indirect**	**Cumulative (impacts compounded over time and space)**	**Level of Vulnerability (and time frame)**	**Consequences of each area of concern**
Cyber Security	Partial to total shutdown of public and private transportation operations.	Quality infrastructure Mobility Transportation Choice Safety and Security Economic Competitiveness	Quality Places		Moderately high risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service, and connectivity due to hacking Loss of economic efficiency Major threat to safety and security
Terrorism	Falling demand for travel both nationally and internationally .	Mobility Transportation Choice Safety and Security Economic Competitiveness	Quality Places Quality infrastructure	Environmental Stewardship	High risk in short term; high risk in mid-to-long term	Transportation network disruptions. Loss of mobility, service, and connectivity Loss of life and injury Loss of economic efficiency Major threat to safety and security

Interactions with Potential Future FTP Scenarios

As the characteristics surrounding Return to Historic Growth scenario center on increasing population, specifically on the urban fringe, there will be an increasing concentration of future population growth. The ensuing concentration of population growth will likely exacerbate congestion and traffic issues, especially if new technologies do not catch on and gas prices remain low. Nevertheless, one method of mitigating these negative externalities of population growth is through the use of technology to establish a more connected transportation network. However, increasing population causing increasing connectivity will lead to consequences surrounding the increasing severity of any cyber breaches of the transportation system (Table 21) (Taeihagh and Lim, 2018). As more people connect through transit applications and more connected modes of transportation, the impacts of cyber-attacks become more widespread, affecting larger segments of the population.

Similarly, the increasing population and geographical concentration of this growth also change the severity of any potential threats or acts of terrorism. Similar to the implications of expanded connectivity, the continuing concentration of the population increases the severity of any threats or attacks of terrorism, due to more people residing within the affected area. Consequently, the return to historic growth scenario may lead to a changing influence of urban hierarchy, leading to increasing geographic vulnerability for large concentrations of the population. For example, megaregions may dominate the global economic activities of the state.

The characteristics of the Rural Rediscovery scenario focus on expanding Florida's agricultural sector and enabling the production of specialized manufactured

goods, and can be implemented through an increased investment in freight routes, terminals, airports, and other infrastructure in rural and inland areas to establish better farm-to-market transportation. To accomplish a more efficient farm-to-market transportation system would require the incorporation of a more connected transportation system. However, return to rural rediscovery would lead to increased travel distances and more reliance on connectivity to major transportation corridors. As such, the consequences of rural rediscovery, in terms of cyber security, revolve around changing development patterns, which alter the magnitude of connectivity disruptions. For instance, accessing major transportation corridors for the movement of agricultural goods intensifies through the Rural Rediscovery scenario. Consequently, any cyber breach that hinders access to these major corridors has the potential to substantially disrupt the movement of goods and people, and subsequently the economic productivity and competitiveness of the state.

While the internalization of economic activities within the agricultural and manufacturing sectors of the state economy will reduce our dependence on global imports, the internalization of such activities may create more vulnerability for the state in regards to any threats or acts of terrorism. More specifically, the magnitude of disruptions from any act of terrorism has the potential to undermine the functionality of the state's economy and the accessibility to goods and services by the population. Through increasing the agricultural and manufacturing production within the state, there may be a decreasing reliance on importing goods. Consequently, such internal economic production may change global trade relationships, specifically through

exporting and importing, which will affect the trends of transporting goods within the state.

The characteristics associated with the Global Trade Hub scenario largely focus on economic activities. If Florida's seaports and airports were to become leading export and import gateways and if Florida's agricultural and manufactured goods become increasingly exported to global markets with increasing travelers visiting Florida, the state will become increasingly vulnerable to breaches in cyber security and terrorism, as well as a changing role in the global economy. An increase in the number of travelers to the state and more seaport and airport activity will result in further needs of a more multimodal transportation system. However, the changing movement of travelers throughout the state and the manners in which they move will result in changing influences of any cyber security attacks on the mobility of goods and people.

While the consequences of cyber security for the Global Trade Hub scenario focus on the movement of goods and people in relation to economic activity and overall mobility, the threats or acts of terrorism are more concerned with the increasing number of visitors to the state and the increasing seaport and airport activity. Specifically, any threats or acts of terrorism directly affect the attractiveness of a destination for travelers and economic expansion. As other characteristics of the Global Trade Hub scenario posit Florida becoming a potential destination for multinational corporations, it is important to understand the influence of the location of these corporations and the changing urban hierarchy.

The characteristics surrounding the Innovation Hub scenario largely focus on the labor composition of the state, the potential for Florida to become a global leader in

innovation industries, and expanding transportation choices, specifically through deploying autonomous and connected vehicles. Through the heavy incorporation of technology to achieve the Innovation Hub scenario, such as deploying autonomous and connected vehicles, there will be increasing susceptibility to cyber-attacks. Such increasing reliance on technology for mobility and logistics will greatly improve innovation in transportation, as well as other innovative industries. However, this increasing reliance causes any negative implications through cyber breaches to be magnified. Moreover, progressing towards the Innovation Hub scenario will lead to increasing populations in urban areas, which will compound the severity of any threats or, acts of terrorism. Specifically, these threats or attacks will affect larger segments of the population, due to the growing concentration of the population, especially within Florida's SoFlo megaregion, where the majority of innovation is expected to occur. Thus, Florida's increasing influence in the global economy through its megaregion has the potential to dramatically affect the potential to attain the Innovation Hub scenario.

The Risks on the Horizon scenario focuses on adapting infrastructure to prepare for extreme weather events, a decreasing migration trend to the state, and stagnating or declining economic activities. The increasing frequency of extreme weather events creates uncertainty surrounding their implications for autonomous vehicles and the connectivity of the transportation system. Because of extreme weather events, there may be disruptions in transportation cyber-physical infrastructure and between the connectivity of vehicles to other vehicles and to infrastructure. Any threats or acts of terrorism have the potential to affect migration to the state, tourism, and the economy. As identified through literature review, anthropogenic causes, such as terrorism, have

the potential to impact mobility and economic activities more so than natural disasters and socioeconomic conditions.

Thus, the increasing mobility of people and goods, through globalization, is exacerbating the risks associated with various global issues. This is further exemplified by the influence of the global economy on the Risks on the Horizon scenario through the potential for any future global recessions and any changes in trade relationships. The consequences associated with the uncertainties of the global economy ultimately impact import and export trends of the state, which will subsequently affect seaport activity and trucking operations across Florida.

Table 21. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Global Issues Including Security

Scenarios from FTP	Uncertainties	Uncertainty Leading to Risk	Consequences
Return to Historic Growth	Cyber Security	Increasing population causing increasing connectivity	Changing severity of any breaches
	Terrorism	Increases in population and concentrated geographical distribution	Changing severity of any threats or attacks
	Global Economy	Urbanization and SoFlo Megaregion	Changing influence of urban hierarchy
Rural Rediscovery	Cyber Security	Increasing travel distances and reliance on connectivity to major transportation corridors	Changing development patterns alter magnitude of connectivity disruptions
	Terrorism	Changing reliance on importing agricultural and manufactured goods	Changing magnitude of disruptions caused by threats or attacks due to internalizing economic relationships
	Global Economy	Reliance on importing agricultural and manufactured goods	Changing global trade Relationships
Global Trade Hub	Cyber Security	Increase in travelers moving throughout the state Increasing reliance on multimodal transportation of goods	Changing influence of cyber breaches on mobility of goods and people
	Terrorism	Increase in travelers coming to the state Increasing airport and seaport activity	Threats or attacks of terrorism impact attractiveness of destination for travelers and economic expansion

Table 21. Uncertainties, Risk, and Consequences for FTP Scenarios Related to Changes in Global Issues Including Security (continued)			
Scenarios from FTP	**Uncertainties**	**Uncertainty Leading to Risk**	**Consequences**
Global Trade Hub (continued)	Global Economy	Destination for multinational corporations	Changing influence of urban hierarchy
Innovation Hub	Cyber Security	Deployment of autonomous and connected vehicles	Increasing reliance on technology for mobility and logistics
	Terrorism	Increasing population densities around urban areas	More concentration of population leads to increasing severity of terrorist threats or attacks
	Global Economy	Global leader in IT, Aerospace, and Other Innovation Industries	Changing relationship of Economic Development Megaregions (SoFlo)
Risks on the Horizon	Cyber Security	Extreme weather events on automation and connectivity	Disruptions in Infrastructure Disruptions in connectivity Sensor Recognition
	Terrorism	Influence on tourism and economy	Slowdown of migrants Stalling of economic activities
	Global Economy	Global Recessions Changing Trade Relationships	Changes in import and export trends

Table 22 summarizes the likelihood, frequency, vulnerability, threshold, and consequences regarding risks related to global issues including security. Both increasing global access to technology and global movement of goods and people are expected. Conversely, it is likely that changes in international trade relations and increasing political polarization will occur, while the likelihood of cyber breaches and threats or acts of terrorism are probable. The frequency of all risks related to global issues including security are ongoing. While vulnerability and consequences are discussed heavily in previous sections, it should be noted that increasing political polarization, cyber breaches, and threats or acts of terrorism will have extreme consequences.

Table 22. Global Issues Including Security Risk Matrix					
Risk	Likelihood	Frequency	Vulnerability	Threshold	Consequences
Increasing Global Access to Technology	Expected	Ongoing	Moderate	No	Moderate
Global Movement of Goods and People	Expected	Ongoing	Moderate	No	Moderate
Changes in International Trade Relations	Likely	Ongoing	High	No	Moderate
Increasing Political Polarization	Likely	Ongoing	High	No	Extreme
Cyber Breaches	Probable	Ongoing	High	No	Extreme
Threats or Acts of Terrorism	Probable	Ongoing	High	No	Extreme

Synergies

As previously discussed, the interrelations of the five broad sources of risk create a greater set of synergistic risks. The synergistic risks multiply through their incorporation with the FTP goals, as has been discussed in the sections about the interactions between the broad sources of risk and the FTP goals. This is best depicted throughout the discussion of the cumulative effects, particularly for the goals of promoting environmental stewardship and creating quality places, largely due to the impacts that other goals have on the environment and the quality of a place. However, it is important to note that many of these synergistic effects occur in reciprocally with other goals and identified risks. For example, the travel behavior of the population may change as a results of the change in population structure and the inception of new modal options through transportation advancements. In turn, these changes will influence the goals of travel choice and mobility, which will impact safety and security, while safety and security reciprocally will affect travel choice and mobility options for the population.

Thus, one singular area of concern that has been identified throughout this research process is the potential to impact a wide range of risks, goals, and other areas of concern. As such, Figure 2 denotes the complexity of the synergistic risks in the transportation sector. Although not comprehensive of all risks, Figure 2 represents the interconnectedness and the scalability of risk, while also denoting the most pertinent relationships that manifest throughout such interrelations.

The increases in population and the associated changes in demographic composition will interact with the environmental, fiscal, and technological risks to create other challenges in transportation planning. For aging populations, the availability of new technologies, such as SAVs and CAVs, may provide additional mobility options when they can no longer drive. However, these modes may be more expensive than existing modes and they may not be universally available to all populations based upon geographic location.

A major challenge in predicting the risk associated with population and demographic change is that we do not know where people will choose to live. If the population continues to move to urban areas, the state and local governments will have increased pressure to provide additional transportation options and will have challenges in providing them due to already congested transportation facilities. At the same time, urban areas are likely to have increased demand for last-mile freight deliveries due to increasing demand for online shopping for goods and services. Urban areas, throughout the United States have seen a decline in demand for transit likely due to the availability of transportation network company (TNC) services (Lewyn, 2018). The structure of transportation finance creates another set of risks for these communities with the need to provide these collective modes of transportation with diminished capability to raise revenue to support them.

If populations choose to move to coastal areas, and if the risk of flooding and other natural disasters increases, the state will need to rethink policies for evacuation. Sea level rise may increase the severity of storms and the number of people who need to evacuate. Additionally, sea level rise throughout the Caribbean may increase the

number of climate change or natural disaster migrants, such as Puerto Ricans who moved to Florida after Hurricane Maria. After Hurricane Irma, state leaders may need to re-evaluate the feasibility of evacuating large portions of the population. Technological advances, like automation, could further exacerbate these interrelated risks. For instance, if we progress towards a fully autonomous transportation system through CAVs, it may become more suitable for residents to shelter in place during hurricanes, rather than evacuate, due to timeliness and limits in the capacity of the autonomous transportation system.

Florida's economy is heavily dependent upon tourism, agriculture and construction (Meeting 5). The economy is likely to change as new transportation technologies and associated opportunities occur. The changes in employment associated with new technologies and how they will affect local and regional economies is a matter of considerable uncertainty. For example, will changes to autonomous and connected trucks reduce the amount of employment in the trucking industry in Florida, and if so, how quickly? Will increased use of telecommunications to make online purchases reduce the number of retail establishments and their associated employment or will it result in increases in employment in warehouses and other distribution centers that will speed the delivery of products? Will these new jobs demand a higher wage than the routine and low-skill jobs that they are replacing?

As is discussed below, the economic impacts of climate changes and the associated impacts will pose as an increasing risk for the State of Florida. The U.S. Global Climate Change Research Program in its Fourth National Climate Assessment states,

> In the absence of significant global mitigation action and regional adaptation efforts, rising temperatures, sea level rise, and changes in extreme events are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of our communities (p. 12)

Because of its location in the Southeastern United States, Florida is vulnerable to disruptions from hurricanes, rising temperatures and sea level rise. Communities throughout the state will need to identify strategies to mitigate and adapt to the impacts of climate change and the associated impacts.

The changes to the state resulting from increased temporary and permanent flooding and increased storm frequency and intensity have the potential to change many aspects of the state economy and at its people. More frequent flooding and higher storm surge damage are likely to cause both residents and migrants to move inland or out of state (Meeting 2). These changes are likely to put pressure on inland transportation systems, where additional transportation investments would be required to serve the increase in population. If people chose to move to other states, the state would have decreased revenues for a variety of activities including transportation investment, operations, and maintenance. Another impact of the changes in frequency and intensity of storms and the associated flood risk is that fewer people might visit Florida due to concerns about the storms. This could affect the revenues, employment and other aspects of the Florida economy.

The damage associated with flooding – both permanent and episodic (storm-based) – of transportation systems is likely to have a major set of interconnected challenges that cumulatively could put the state and its economy at risk (Table 12). The increased damage associated with storms could then increase the amount of damage to

coastal properties that would lead, in turn, to increases in homeowners' insurance and decreases in property values. Over time, the increased risk could make Florida less competitive with other states for new residents. This could lead to a decrease in the rate of growth, a decline in population, or changes in locational decisions of new and existing residents to inland areas. As is discussed above, if residents change their settlement pattern, the state would need to build more transportation facilities inland. Ultimately, all these changes in coastal communities could increase costs and decrease the state's economic competitiveness.

We have witnessed major improvements in technology, especially in the transportation sector. The exponential rise of app-based ride hailing services is one of the prime example of how quickly technology can change the market. These services have given more choices to consumers; however, they have caused a significant reduction in the state and local revenues. These app-based services are not subject to the rental car surcharge. The estimated annual loss in rental car surcharge collection is $72 million or 7.7 percent and the app-based services are partially responsible for this drop (FSEA, FHAC & FEDR, 2017).

Similarly, public revenues related to the transportation sector are being reduced as drivers purchase and use fuel-efficient vehicles and alternative fuel sources. Many people are choosing cars with higher fuel efficiencies or alternative fuel sources because of higher social awareness, wanting to save money on gas, wanting to be eco-friendly or wanting to reduce the impact from fluctuations in the price of gas. AVs and SAVs are likely to be adopted for similar reasons, as they are often suggested to reduce VMT and congestion. Yet all of the changes in technology are likely to reduce the

revenues the state receives from vehicles and reduce the ability of the state to continue to make investments in transportation.

However, the notion of full autonomy, itself, causes a ripple effect of further implementation and policy risks through vulnerable sub-groups of the population. This is best exemplified by the expansion of services to groups previously excluded or underserved, such as that of the non-driving older adults (65 and older) and youthful population subgroups (15 and younger). As a result, licensure and the potential requirement for an able-bodied adult to be in the car may be a prerequisite to the use of lower levels of automation. This is especially important during what is expected to be a transition towards autonomy, where control is more incrementally taken away from humans and placed in the “hands” of technology, thus necessitating the presence of a qualified and able-bodied person

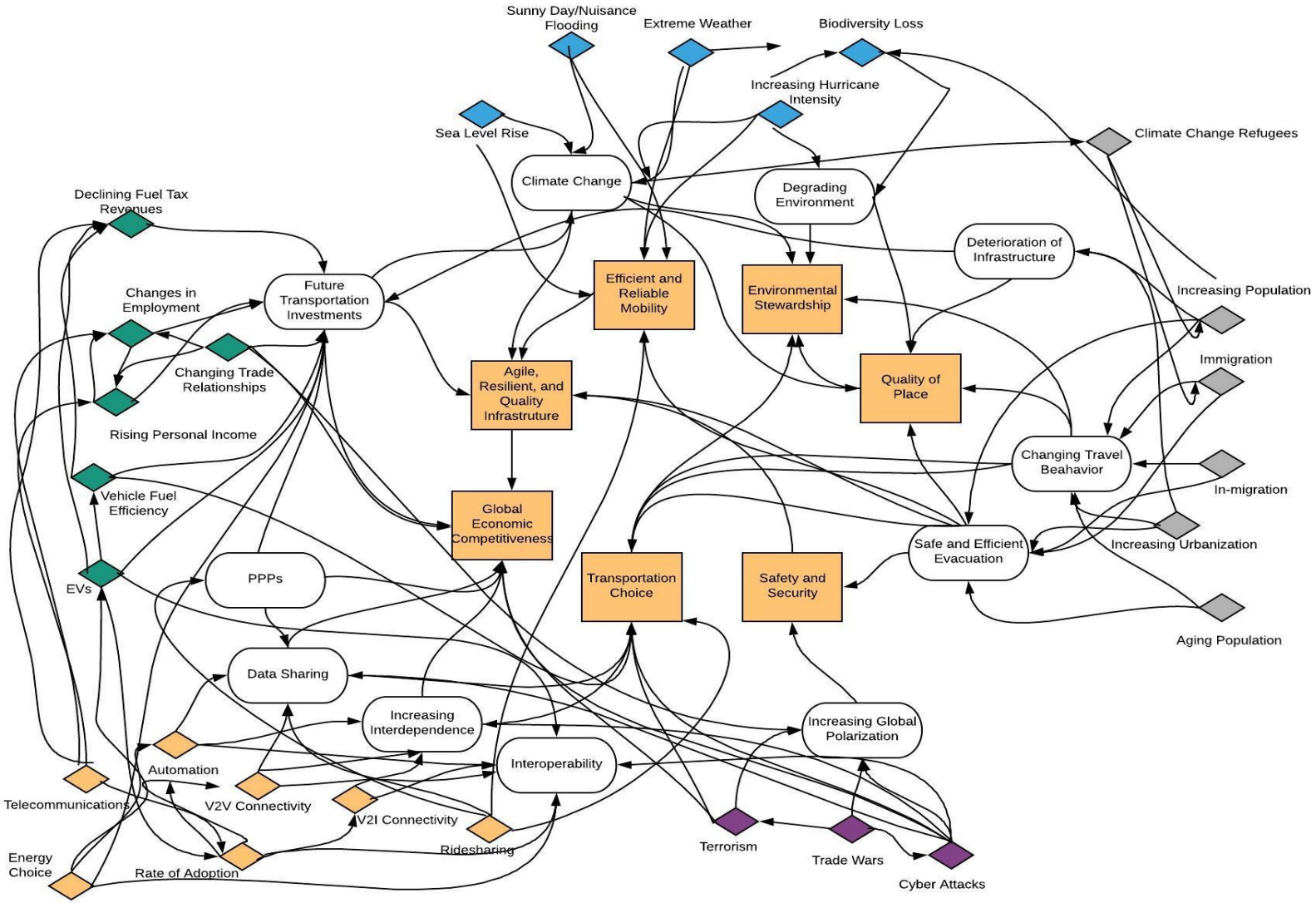

Figure 2. Web of Transportation Risks

Best Practices

For population and demographics, statewide best practices were selected based on mutually shared criteria with Florida. Texas and California were chosen as large, multi-racial, multi-ethnic states that are good examples of how to plan for growth (Table 23). Best practices from New Mexico have been incorporated here due to their increasingly aging population structure. Examples of best practices in multimodal corridor planning were identified from a National Cooperative Highway Research Program Scan on Successful Intermodal Corridors.

Table 23. Best Practices in Addressing Demographic Risks

Demographic Risk Catalysts	Examples of Risk	Best Practices
Increase in Population	➢ Impact on physical infrastructure ➢ Planning for increasing capacity	➢ Texas ➢ California
Increase in Aging Population	➢ Planning for different modes of travel and movement	➢ Texas ➢ New Mexico ➢ California Multimodal Corridor Planning
Change in Demographic Composition	➢ Change in travel patterns ➢ Barriers to travel	➢ California ➢ East Central Florida Regional Planning Council

In California, to plan and adapt for the high level of growth, the state has created the California Strategic Growth Council (CSGC) (CSGC, n. d.-a). The CSGC has partnered with private companies to create interactive tools to help visualize population growth. A tool called the ‘UrbanFootprint’ allows planners, policymakers, and citizens to determine the outcome and get a visual of where growth may occur (CSGC, n. d.-b). Florida already visualizes future populations through projections made by BEBR at the

county level, and in its geographic information system (GIS)-based small-area models, available in some parts of the state. In addition, the Florida 2070 study by the 1000 Friends of Florida is a good example of evaluating the implications of different geographic distributions of BEBR's forecasted growth. This would be a good starting point for developing and evaluating statewide growth scenarios, which are essential to informing future planning processes.

The Texas Department of Transportation (TxDOT) offers various best practices for accommodating population growth and aging populations. TxDOT has incorporated scenario planning into its LRTP using three different scenarios when planning for population increase. Scenario planning allows Texas to be flexible and adaptable to varying increases of population. Additionally, Texas also uses 'County Categorization' to plan for where population growth is expected to take place by analyzing the following variables: county population, the population of the largest city within the county, if the county contains an urbanized area of the MPO, proximity to other MPOs, and the commuting characteristics of residents within the county (TxDOT, 2010). Regarding aging population, Texas is adapting to the increase of baby boomers by improving multi-mobile access, providing 'travel choice' and improving its already present regional paths and bikeway trails.

Another state that has been planning for an aging population is New Mexico. While multimodal transportation options are a longer-term recommendation, one can look at New Mexico's efforts for ideas about how to supplement this transition with alternative modes of transportation specifically for older adults. Throughout its LRTP, NMDOT highlights facts regarding its aging population and then strategic actions to

work through associated vulnerabilities. Aside from having goals to support this population, New Mexico also has an Aging and Long-Term Services Department that offers medical, social and transportation assistance to older adults and adults with disabilities. The department has four area offices around the state that allow for specialized care based on the region in which the elderly populations are located. (NMDOT, 2015)

Another best practice that addresses the needs of Florida's changing population is to plan for intermodal corridors through intermodal corridor management, which attempts "to meet transportation demand at the least social and economic costs while maximizing return on previous and future investments in infrastructure and services" Wallace et al., 2016: p. ES-1). "The concept of what constitutes a transportation corridor is, in practice, elastic, ranging from short highway segments to longer highway segments to multiple modes of transportation sharing a linear course that may stretch between cities or between states" (Wallace et al., 2016: p. ES-1). Intermodal corridor management brings together the principles of multimodal corridor planning, integrated corridor management (ICM) and active traffic management (Wallace, et al., 2016). Intermodal corridor management

> recognizes that multiple modes can satisfy a variety of travel demands within a corridor and that most movement of people, goods, information, and services in a corridor involves movement between modes. … Intermodal corridor management presents a strategic way to determine the best investments in multiple modes to improve a transportation corridor's productivity to support longer-term social goals related to economy, environment, and community development and quality of life. (Wallace et al., 2016).

The Association of State Highway and Transportation Officials (AASHTO) completed a scan of successful intermodal corridor management practices with

representation from Arizona, California, Florida, Maryland, Massachusetts, New York, North Carolina, Oregon, Utah and Virginia. The report from this scan identifies several best practices in intermodal corridor management: corridor visions and goals, collaboration, leadership, systems approach, data, customer focused performance measurement/management, outreach, funding and sustainability. The efforts of the California Department of Transportation (Caltrans) are particularly noteworthy due to their adoption of guidance and policies, including Context-Sensitive Solutions; Complete Streets; Complete Intersections; and Main Street, California: A Guide for Improving Community and Transportation Vitality. Caltrans has developed local pilot projects to incorporate state policy initiatives into local projects, and also uses a mobility pyramid in its corridor management decision-making (Figure 3). Caltrans has also adopted the policy of Integrated Corridor Management, which uses a variety of tools like high occupancy-toll-lanes, bus-rapid-transit lanes, and high-occupancy-vehicle lanes as ways to manage demand and increase capacity (Caltrans, 2016). One advantage of an integrated multimodal system is increased utilization of public infrastructure for all modes of travel (Caltrans, 2018).

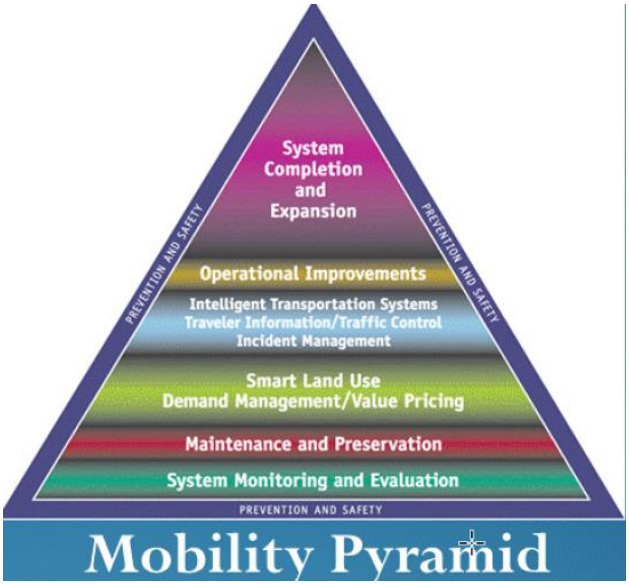

Figure 3. Caltrans' Mobility Pyramid (Wallace et al., 2016: p. AD-6)

The California Legislature also passed legislation that created the Solutions for Congested Corridors Program (SCCP), which provides $250 million annually for projects that achieve a balanced set of transportation, environmental and community access improvements to reduce congestion (State of California, n. d.).
Projects have been funded under this program in geographically dispersed locations for diverse projects. "Eligible project elements with the corridor plans may include improvements to state highways, local streets and roads, rail facilities, public transit facilities, bicycles and pedestrian facilities, and restoration or preservation work that protects critical local habitat or open space" (State of California, n. d, n. p).

The FDOT District 5 developed a Multimodal Corridor Planning Guidebook in 2013 that outlines a multimodal corridor planning process within the existing FDOT project development process (Figure 4). This process would provide the information for the next phase of any transportation project including order of magnitude costs, feasible implementation schedule and the information necessary to scope out a project (FDOT

District 5, 2013). As can be seen in Figure 5, the multimodal corridor planning process could result in land use, transportation or other strategies and, as is shown in Figure 6, the transportation strategies lead to project development and environmental (PD&E) or concept development. The corridor planning process would include three phases: (1) define the problem; (2) define the guiding principles; and (3) define and select alternatives (Figure 6). The process would be scaled depending upon the nature of the problem.

Figure 4. Timing of Multimodal Corridor Planning in FDOT District 5 Multimodal Planning (FDOT District 5, 2013: p. 18)

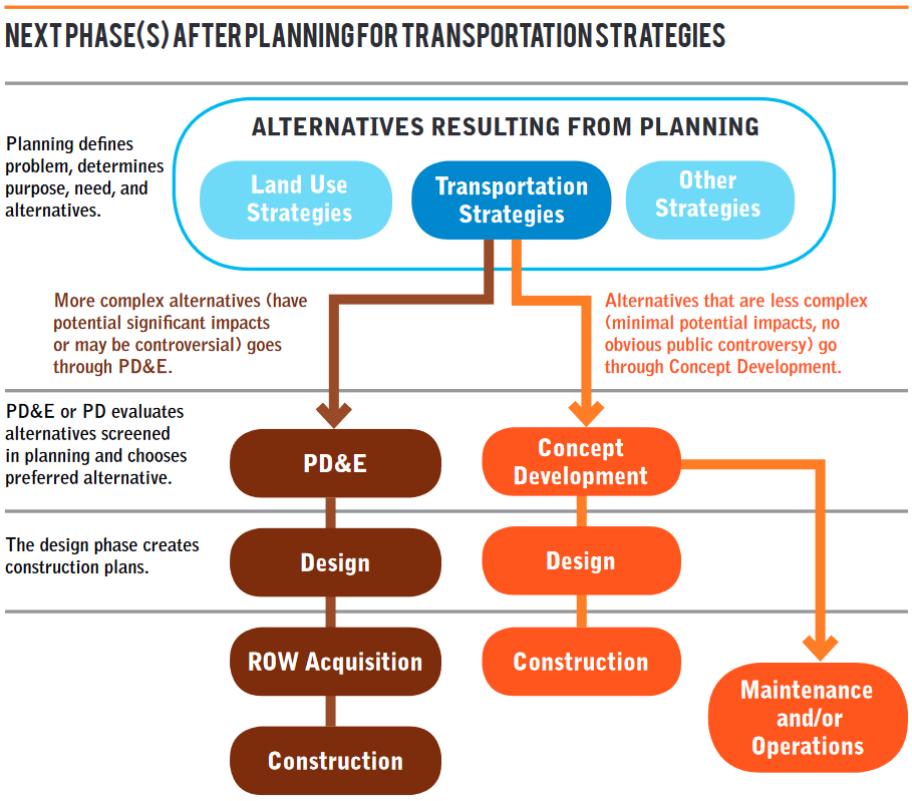

Figure 5. Phases after Multimodal Corridor Planning Process (FDOT District 5, 2013: 27)

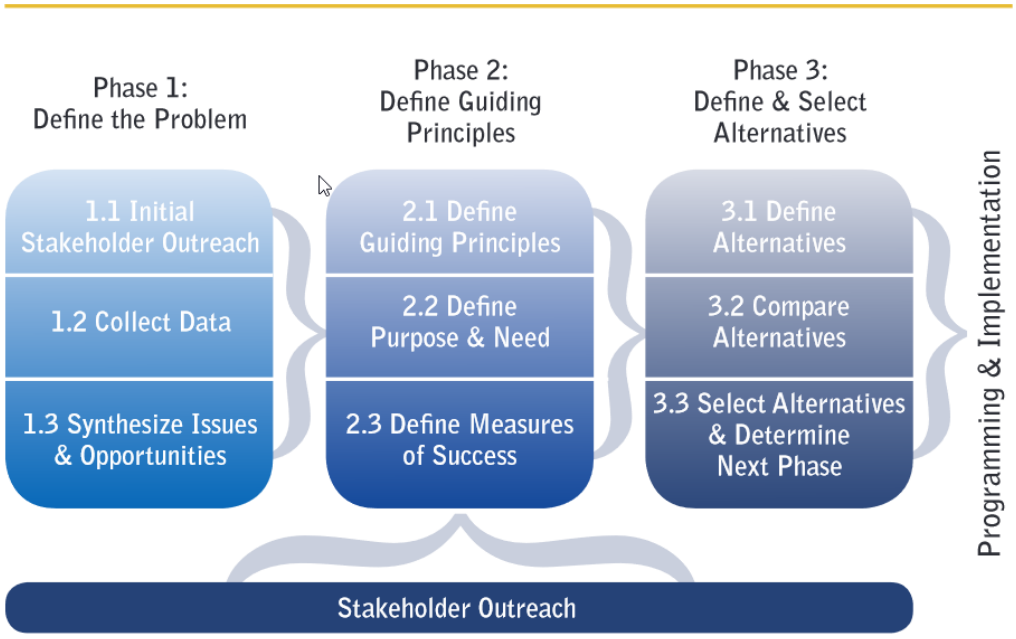

Figure 6. Corridor Management Plan Planning Process (FDOT District 5, 2013: p. 24).

Planning for intermodal corridors can balance capacity for all modes along a corridor to facilitate economic goals of states and regions. In response to increasing urbanization, particularly in major urban areas such as San Juan, Puerto Rico has proposed to include new developments of corridors connecting pertinent locales within the urban region. Florida will similarly need to plan for additional connectivity within and to its economic megaregion, SoFlo, which connects Miami, Tampa, and Orlando.

While megaregions have sprouted up all over the U.S., Louisiana provides the only plan with transportation goals, policies, and objectives directly related to the development of a megaregion through what the state deems as “megaprojects”. Although not yet home to a megaregion, Louisiana’s state plan presents some best practices for the conceptualization, prioritization and development of megaprojects. Specifically, Louisiana excelled at utilizing a participatory planning approach for incorporating the ideas of municipal level transportation authorities to conceptualize potential megaprojects. The state also successfully incorporated vertical coordination across various departments and agencies for the conceptualization and prioritization process. For example, each metropolitan planning organization (MPO) executive director, planning and development district executive director, and LDOTD district administrator was asked to prioritize megaprojects in their area (LDOTD, 2015).

Although the California plan does not explicitly discuss megaregions, they include transportation-related economic development initiatives such as improving passenger and freight-related transportation to meet their economic, social, and environmental goals in their plan (Caltrans, 2016). Meeting these goals will require adopting new technology to maximize their limited resources (Caltrans, 2016, 2018).

For example, Caltrans sees AVs as a major component of their LRTP specifically because AV technology can increase capacity on limited road infrastructure, increase safety, and reduce emissions (Caltrans, 2016, 2018). As is discussed above, their integrated corridor management and the mobility pyramid are all a part of enhancing capacity using various strategies to maximize the capacity of transportation corridors.

In addition to the changing economy, Florida's transportation system needs to react to changes in revenues with aging infrastructure. Therefore, the examination of best practices goes beyond economic development and megaregion initiatives to addressing both the infrastructure and revenue risks. The major challenge California is facing is of revenue shortfalls and aging infrastructure. Aging infrastructure needs to be modernized and maintained to meet the expected increased demand, which requires adequate funding. The revenue resources in California are user fees, including fuel taxes, sales taxes, vehicle weight fees, transit fares, and tolls (Caltrans, 2016).

The dependence on transportation financing from motor vehicle fuel taxes, the essential wellspring of GHG and criteria toxin emissions in California is contradictory with their climate and air quality objectives (Caltrans, 2016). Assembly Bill (AB) 32 and Senate Bill (SB) 375 promote a reduction of GHG emissions from transportation sources by promoting active transportation and transit and requiring cleaner fuels and cleaner vehicle technology (Caltrans, 2016). This leads to a decrease in transportation maintenance and improvements funds, as household expenditure on fuel purchases are declining. Thus, the state needs new sources of revenues. The California Transportation Plan 2040 Cap-and-Trade program promotes the reduction of GHG emission, which helps generate revenues, and develops a data-driven methodology to

help ensure funding is put to the best possible use, public-private partnership (PPP) and Fix-it-first program that focuses on system maintenance rather than expansion.

Similarly, Texas is facing serious funding issues. TxDOT plans to maximize the use of existing funding through performance-based project selections and operational enhancements to improve efficiency throughout the department. However, these initiatives will not close the funding gap between needs and revenues. TxDOT will need to work closely with state and local elected officials to increase existing revenues and create new capital. The following are the sustainable revenue sources: motor vehicle sales tax, PPPs, Texas Mobility Fund, transportation reinvestment zones, VMT tax, index or increase the motor fuel tax, increase vehicle registration fees, and tolling.

As a part of the plan implementation, TxDOT developed a bilingual interactive planning scenario tool using MetroQuest, to enable the public and other stakeholders to envision systemic impacts and trade-offs in performance due to shifting transportation investment priorities (TxDOT, 2015). They developed four scenarios – system preservation, metropolitan mobility, connectivity and freight mobility, and a balanced approach - to help stakeholders understand tradeoffs in spending limited resources. Each approach was designed to advance the performance of the transportation system in a targeted way. Furthermore, TxDOT is in the process of implementing its first electronic Statewide Transportation Improvement Program (STIP); this tool will enable a “real-time” financial evaluation and assessment of projects constructed or implemented against available revenues to improve resource allocation and streamline project delivery (TxDOT, 2015).

The major challenge the State of Washington is facing is of revenue shortfalls and aging infrastructure. Washington's major revenue sources are state and federal motor fuel tax. The state identifies a need to address challenges including aging infrastructure, future increments in travel demand to help a developing populace and economy, the vulnerability of federal funding, a potential future decrease in total gas tax as fleet fuel economy is enhanced, and the decrease in gas tax revenues resulting from inflation. Washington's priority is to use the primary funding to preserve existing infrastructure. The changes reflect the State's increasing need to secure significant revenue sources aside from the motor fuel tax, including driver fees and toll revenues.

Based on Washington's sources of revenue, including licenses, permits, and fees, Washington will likely finance capital-intensive megaprojects with toll-backed revenue bonds. Thus, users will fund any extensive transportation network improvement and major rehabilitation projects in the future (WSDOT, 2015). Even with enhanced proficiency, the state considers a scope of alternative revenues sources to address the growing demand and effect of inflation including increased fuel taxes and vehicle fees; evaluation of road usage charges; use tolls strategically; adjust the ferry capital surcharge; use transportation benefits districts; use street maintenance utilities; and allow local fuel taxes (WSDOT, 2015). The WTP 2035 also mentions expanding partnerships with the private sector and exploring the viability of Tax Increment Financing (TIF) (WSDOT, 2015).

The major challenge Georgia is facing is of revenue shortfalls. Georgia's revenue sources are FHWA Funds, FTA Grants, State Motor Fuel Excise Taxes and State General Fund Appropriations (GDOT, 2016). Georgia passed a new Transportation

Funding Act of 2015, which specifically represents the new state transportation funding sources. The following changes were included in the bill:

- State Motor Fuel Excise Tax Rates were raised after eliminating the state motor fuel sales tax. Further, the tax rates were indexed to inflation and to the rising fuel efficiency standards of vehicles.
- Hotel/Motel Nightly Fee was promulgated for each calendar day a room, lodging, or accommodations are rented or leased.
- Heavy Vehicle Annual Impact Fee was implemented.
- Alternative Fuel Vehicle Fees was implemented for commercial and non-commercial vehicles.
- Tax Credits on low/zero-emission vehicles were eliminated

The Oregon Department of Transportation has implemented a collaborative, web-based, least-cost planning tool, called Mosaic, that allows comparisons of different transportation projects and bundles of projects to find the most cost-effective solutions that address a variety of social, environmental and financial costs and benefits of transportation plans (Wallace, et al., 2016). ODOT developed the tool that is scalable based upon the jurisdiction's transportation staff, available data and needs in collaboration with local, regional and statewide stakeholders (ODOT, n. d.). For example, the tool works for both communities that use the regional transportation models and those that do not (ODOT, 2014). Mosaic uses the following indicator categories for which costs and benefits are monetized and measured using more specific indicators metrics: accessibility/connectivity, economic vitality; environmental stewardship, equity, funding the transportation system/finance, land use and growth

management, mobility, quality of life and livability, safety and security. Mosaic provides the basis for discussions among stakeholders about the values and assumptions in proposed transportation projects.

The challenges associated with generating revenues for transportation infrastructure will be challenged by the environmental impacts associated with sea level rise, storm surge, and other climate-related change to the weather, such as temperature increases, heavy precipitation, and increasing hurricane intensity (Table 24). The

Environmental Areas of Concern	Risk Examples	Best Practices	Documentation
Sea Level Rise and Storm Surge	➢ Structural integrity of infrastructure ➢ Reduction of movement ➢ Population distribution	Adaptation and Resilience Projects Legislation and Policy Initiatives Improving Stormwater Infrastructure Funding for transportation resilience	Louisiana Coastal Adaptation EPA, AASTHO, FHWA Guidelines California GHG Legislation Washington D.C.
Increasing Hurricane Intensity	➢ Coastal infrastructure (roads and critical ➢ Efficiency of evacuation of all modes	Focus on preparedness mitigation before hurricanes occur Temporary flood protection Transportation resilience	Federal Emergency Management Agency (FEMA) Guidelines National Guard U.S. Coast Guard
Temperature Increases	➢ Increase in frequency of maintenance ➢ Delays in construction, maintenance, and movement	Urban Forestry/Urban Cooling Sustainability element of transportation Green Infrastructure/Green Roofs	Environmental Protection Agency California's Sustainability Elements Washington D.C. Environmental Stewardship Initiatives
Increase in Heavy Precipitation Events	➢ Structural integrity/subsidence ➢ Network Disruptions ➢ Weather-related increases in crash rates	Green Infrastructure Continued public education to reduce weather-related crashes Stormwater management BMPs	Environmental Protection Agency Managing Flood Risk City of Portland, Oregon Stormwater Management BMPs

Table 24. Environment Risks and Best Practices

leading best practices include resilience and preparedness planning, investigating scenarios of future development, incorporating a sustainability model into the transportation system, and the use of green infrastructure to mitigate future flood risks and improve stormwater management. Based on our survey of best practices, we found the most promising state-level resources in Louisiana and California and at the federal level, the Environmental Protection Agency (EPA), the FHWA, and the United States Army Corps of Engineers. These state and federal agencies provide guidance and best practices for addressing environmental risks, which can inform the next FTP. The

following section identifies best management practices for addressing project-level transportation planning processes and mitigating environmental risks. It is important to note that many of the environmental risks do not operate in isolation and are often synergistic.

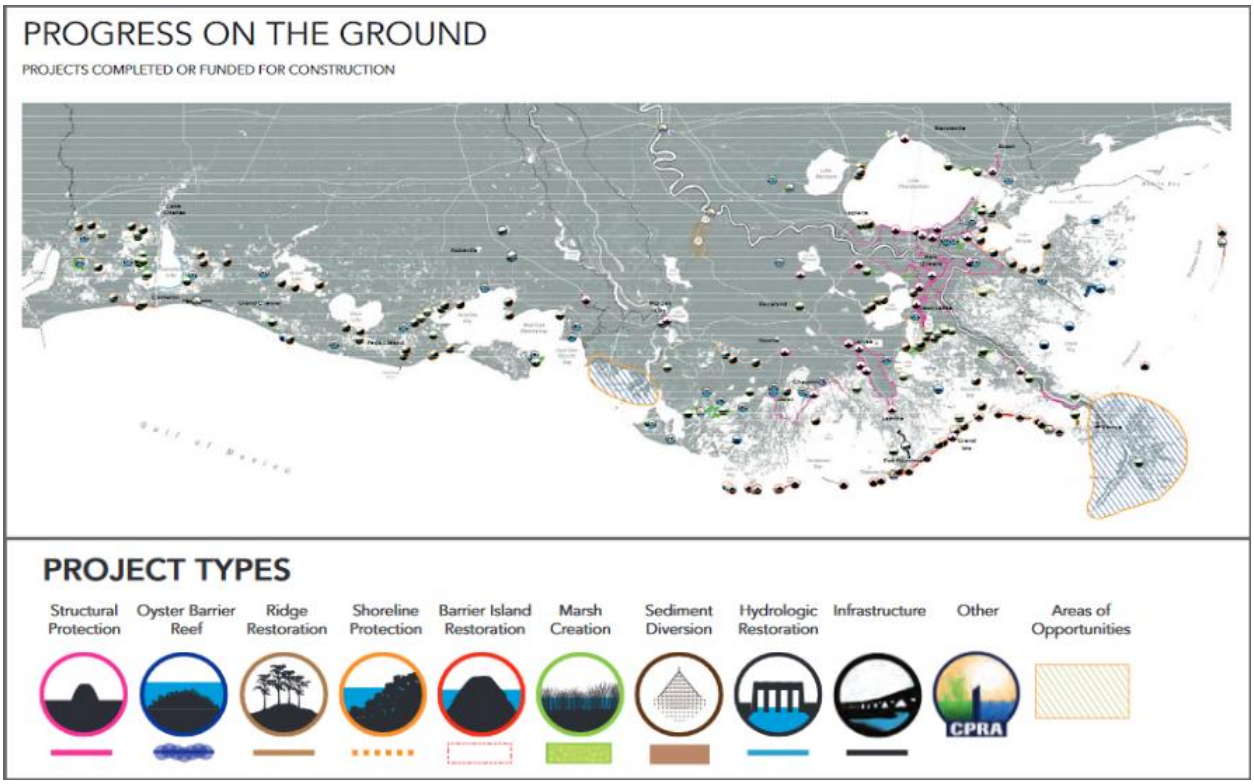

Figure 7. Completed Projects under Louisiana's Coastal Master Plan (CPRA of Louisiana, 2017).

For addressing sea level rise in transportation plans, we found two approaches: (1) requirements that infrastructure projects incorporate elements of adaptation, and (2) implementation of aggressive policies and legislation to address sea level rise and funding for adaptation. Louisiana is the leader in implementing adaptation projects that address coastal flooding and sea level rise projections. Although Louisiana does not include environmental risk in their transportation plan, Louisiana's Coastal Master Plan and Coastal Protection and Restoration Authority (CPRA) guide the transportation plan

to include resilience. Their 2015 Coastal Master Plan includes risk and vulnerability assessments (Figure 7) using the Community Rating System (CRS), budgeting options to fund adaptation projects, comprehensive GIS-based projections of sea level rise and land subsidence along Louisiana's coast, and the implementation of projects to alleviate at-risk areas (CPRA, 2017). These projects include infrastructure updates that protect the transportation system, including floodwalls, levees, and other stormwater management infrastructure. FDOT can adapt Louisiana's approach to protecting and managing the effects of sea level rise by funding infrastructure projects to combat the impacts of sea level rise and storm surge.

Since the G.W. Bush administration, the FHWA has been funding research on climate change impacts to transportation and transferring this research into guidance, tools, and best practices for State DOTs and MPOs. FHWA funded two sentinel studies of climate impacts on transportation systems, "The Gulf Coast Study", which was completed in two distinct phases. Both study phases provided robust analyses and resources for informing transportation agencies on how to identify their system vulnerabilities and how to incorporate climate risks into new asset design, asset management, operations, and maintenance. The FHWA tools and resources include:

- Vulnerability Assessment Framework: a guide on identifying infrastructure vulnerability
- Sensitivity Matrix: a spreadsheet tool for understanding different assets (roads, bridges, airports, ports, pipelines, and rail) sensitivity to 11 climate impacts
- CMIP Climate Data Processing Tool: a tool for downscaling temperature and precipitation projections to a local scale

FDOT should promote these strategies and tools provided by FHWA and facilitate pilot projects, which can test the implementation of these adaptation strategies for Florida's most vulnerable assets.

In addition to implementing resilience projects, the FDOT can pursue policy and legislation to reduce the impacts of climate change. Since the transportation sector is the leading contributor to carbon emissions, the transportation system has a responsibility to reduce its impact on the environment. California and their State Transportation Plan exhibit the most robust and aggressive climate policies in the nation. To do this, California used the federal policy, Executive Order 13690, to establish building guidelines within the floodplain based on federal flood risk management standards (Caltrans, 2016). California and other state DOTs have also used annual emissions testing for all vehicles to ensure adherence to emissions standards for reduction of air pollution. With guidelines that restrict emissions and promote alternative sources of fuel in the transportation sector, as well as successfully implementation of cap-and-trade programs, California's State Transportation Plan and other statewide policies offer best practices that can be applied to Florida's transportation system.

To mitigate the risks associated with increasing hurricane intensity, a set of best practices has been developed at the national level that can help local and state governments with future planning processes. Although many states choose to manage emergencies and natural disasters differently, the overarching theme in emergency and disaster management is preparedness and resilience before the disaster occurs. The main best practices that help inform this conversation on resilience and natural

disasters come from Federal Emergency Management Agency's (FEMA) guiding documents on emergency management and resilience, the U.S. Coast Guard, and the National Guard. The National Institute of Building Sciences researched the cost-benefit of mitigation planning; the study shows that every $1 spent on hazard mitigation and resilience saves $7 in the future from natural disasters and other hazards (National Institute of Building Sciences, 2017). Other forms of preparedness include massive mitigation projects to reduce the impacts of natural disasters and large-scale public awareness and education to bolster the idea of resilience during an emergency.

To mitigate rising temperatures and the urban heat island effect, urban forestry and urban ecology offer effective strategies. One example of an urban forestry initiative is Washington D.C.'s Sustainability and Livability Element, which is a section of their multimodal LRTP. The goal of the Sustainability and Livability Element is to improve urban forestry by implementing enough trees to satisfy a 40% tree canopy (Figure 8) throughout the district. Benefits of urban forestry tactics include increased stormwater retention, more rain capture, and overall a reduction in urban heat island effect (DDOT, 2018). The strategic planting of urban trees and adoption of urban forestry strategies within next FTP can aid temperature reduction and mitigate the risks related to increasing temperatures.

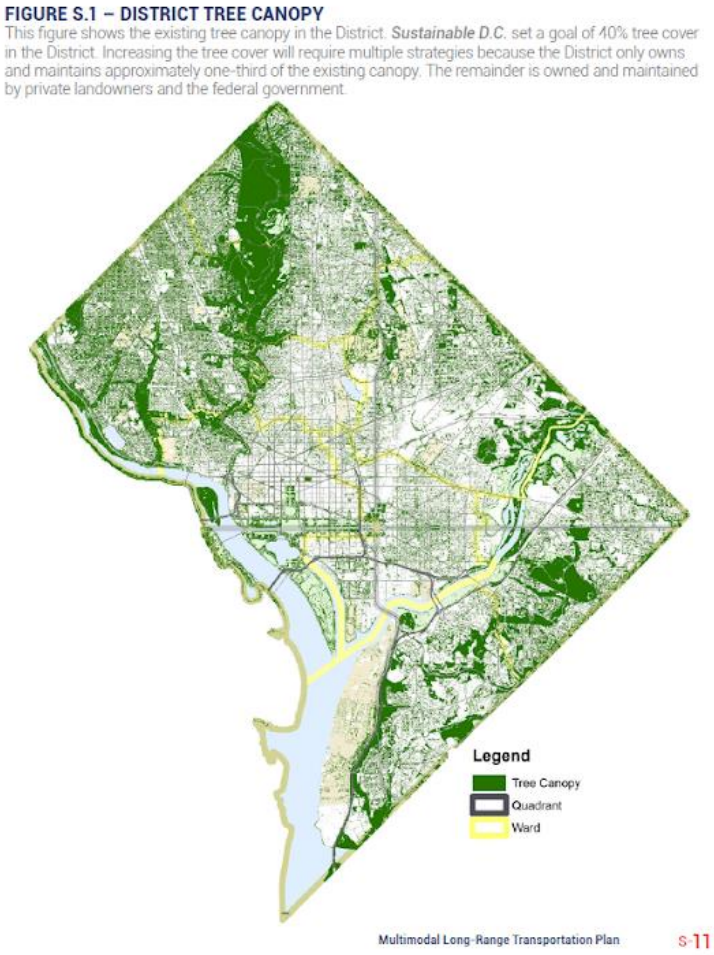

Figure 8. Washington DC Tree Canopy (DDOT, 2014: p. S-11)

Green infrastructure also offers strategies to combat the impacts of increasing temperatures and heat island effect. The addition of plants and other greenspace into the urban city environment increases stormwater retention during rain events, reduces stormwater runoff, and decreases in heat in the overall system. The USEPA provides guidelines on implementing green infrastructure solutions, including permeable pavers, bioswales, retention ponds, and other water capturing systems. Additionally, green roofs offer a source of cooling in the urban center to reduce the overall amount of heat created in the city. The implementation of these green infrastructure strategies can

assist in reducing road deterioration, rail expansion, and other heat-related asset damages.

The risks related to increases in heavy precipitation events revolve around the issue of temporary flooding. Proper stormwater management can reduce the impacts of temporary flooding, but future increases in precipitation must be considered. The USEPA provides a menu of stormwater management best practices to reduce runoff including public education, public involvement, and construction and post-construction standards (US EPA, 2018). Like the role green infrastructure plays in combatting increasing temperatures, the same can be applied to increases in heavy precipitation events. The USEPA provides resources on implementing green infrastructure to better manage stormwater and reduce flood risk. Practices such as permeable parking, rain gardens, bioswales, green roofs, and protection of greenspaces can help absorb rainfall and prevent excess water from overwhelming pipe networks and pooling in streets (US EPA, 2019). FDOT should consider these best practices for mitigating the impacts of heavy precipitation events, particularly regarding updates and maintenance of stormwater management systems.

Another best practice that should be taken into consideration is the usage of environmental vulnerability assessments and tools to evaluate climate change risks at a large scale. Vulnerability assessments allow local and regional governments to identify areas of environmental concern, while also allowing them to make informed decisions about future adaptation options. Many municipalities have conducted citywide vulnerability assessments that examine vulnerability at the local context; however, a broader approach at the regional or state level can be taken to set precedence for the

rest of the state, and to encourage partnerships for adaptation between the local, regional, and state levels. One example of a regional vulnerability assessment comes from New South Wales, where their Office of Environment and Heritage has developed a guide for Integrated Regional Vulnerability Assessments (IRVA) for climate change. The IRVA process assesses various "capital" to evaluate contextual vulnerability to the need for change in government services and operations (NSW OEH, 2013). The five capital assessed in the IRVA process include financial capital, human capital, social capital, natural capital, and physical capital; this holistic approach to a vulnerability assessment ensures that all capital are being examined.

The FHWA prepared a white paper that develops a framework for incorporating shared mobility into multimodal transportation planning, identifies emerging practices and strategies, and makes recommendations for future research (McCoy, Andrew, Glynn & Lyons, 2018). Table 25 summarizes the roles for various levels of government in planning for shared mobility. The State DOTs have a role in regulating shared

Table 25. Potential Roles for Public Agencies in Shared Mobility Planning (McCoy, Andrew, Glynn & Lyons, 2018)

	MPO	Local Government	Transit Agency	State DOT
Regulating shared mobility operations		☑		☑
Regulating the use of public right-of-way and curb space		☑	☑	☑
Data collection, analysis and dissemination	☑	☑	☑	☑
Partnerships with shared mobility providers to complement transit or TDM	☑		☑	
Training and technical assistance for regional partners	☑			
Thought leadership and research	☑			☑
Regional coordination and consensus building	☑			
Integration into transportation plans and programs of projects	☑	☑	☑	☑

mobility operations and the public right-of-way and curb space; data collection, analysis, and dissemination; thought leadership and research; and integration into transportation plans and programs of projects. This white paper also identifies emerging practices and strategies for shared mobility in transportation planning (Table 26). Many of the emerging practices – data access and sharing, regulating use of public infrastructure, strategic planning, operational partnerships, integration of shared mobility services into modeling and forecasting, and technical assistance – can be incorporated into FDOT plans. Because of the complexity of integrating shared mobility into transportation planning, the FDOT has a role to take in bringing stakeholders together, establishing guidelines, funding pilot projects, and conducting research.

Table 26. Emerging Practices and Strategies for Shared Mobility in Transportation Planning (McCoy, Andrew, Glynn & Lyons, 2018)

Category	Emerging Practices and Strategies
Data Access and Sharing	• Negotiating access to shared mobility usage data • Involving third-parties to coordinate data sharing • Including data sharing provisions in partnerships and regulatory agreements
Regulating Use of Public Infrastructure	• Establishing guidelines for use of the public right of way • Regulation of pick-up/drop-off zones for ridesourcing/TNCs
Strategic Planning	• Scenario planning and visioning to grapple with uncertainty • Shared mobility planning programs
Operational Partnerships	• Partnerships to enhance public transit service • Partnerships to enhance ridematching, carpooling, or vanpooling services • Policies for public agency promotion of shared mobility services
Publicly Operated Shared Mobility Services	• Public microtransit pilot projects • Public ridesourcing/TNCs to complement or optimize transit
Integrating Shared Mobility into Modeling and Forecasting	• Incorporating shared mobility in travel surveys • Collecting data continuously • Using off-model approaches to estimating shared mobility impacts
Technical Assistance to Member Local Communities	• Developing model templates for regulations and agreements • MPOs as forums for convening local governments and transportation agencies • Connecting shared mobility to land use planning

The District of Columbia Department of Transportation's (DDOT) LRTP discusses the issue of data sharing. In their plan, it is suggested that the "DDOT should collect and compile data from existing systems and those being planned", while also being cognizant of people's rights and privacy (DDOT, 2014, p. 66). The plan acknowledges the concerns surrounding open data, which lie in access, permissions, and rights, as well as the format of stored data (DDOT, 2014). However, it is important to note that the data sharing aspect was limited to open data sources and did not expand to data sharing under PPP's.

Of all the LRTPs reviewed, the California State Transportation Plan had the most comprehensive policies and goals related to technology risks. Caltrans is considering converting to zero-carbon and near-zero carbon energy sources for transportation a necessary action to meet their midterm and long-term emission goals (Caltrans, 2016). Additionally, Caltrans has goals to improve passenger and freight-related transportation to meet their economic, social, and environmental goals (Caltrans, 2016). To meet these goals will require adopting new technology to maximize their limited resources, of which Caltrans sees AVs as a major component (Caltrans, 2016, 2018). AV technology can be used to increase capacity on limited road infrastructure, increase safety, and reduce emissions (Caltrans, 2016, 2018). V2V technology, smart parking, and V2I technology will become additional tools to manage demand with car-related infrastructure (Caltrans, 2016). SAVs will be used as a first and last mile solution for California's passenger rail network, which will make taking the train for local and intercity travel more convenient (Caltrans, 2018). California will work with trucking companies in the form of PPPs to invest in platooning for trucking (Caltrans, 2016).

California's State Transportation Plan, even with its grand goals, has many policies that Florida could adopt to reduce technology risks.

Outside of modernizing road infrastructure, rail infrastructure is equally as important in their transportation plan. Investing in passenger and freight rail infrastructure is considered another major component of the California State Transportation Plan. Modernizing California's passenger rail network will require significant investment in a variety of technologies (Caltrans, 2018). One major part of passenger rail technology is equipment investment (Caltrans, 2018). The Passenger Rail Investment and Improvement Act of 2008, which was enacted federally, changed the way states dealt with equipment purchases.

To meet their goals to reduce GHG emissions, Caltrans will be adopting zero carbon and near-zero carbon technology for rail equipment. Major rail corridors will be electrified which will increase capacity to allow for more frequent service while meeting California's GHG emission goals (Caltrans, 2018). For non-electrified rail lines, they will invest into low emission diesel equipment and eventually adopt hydrogen fuel cell and battery hybrid equipment (Caltrans, 2018).

Outside of reducing emissions related to freight and passenger rail, Caltrans will convert other modes to zero carbon or near zero carbon equipment (Caltrans, 2018). California wants to reduce their GHG emissions by 40% below 1990 levels by 2030 and 80% below 1990 levels by 2050 (Caltrans, 2016). Instead of focusing on just one technology, Caltrans has decided to take a diverse approach since every mode has their own specific needs (Caltrans, 2018). For public transit, Caltrans will use a variety of technology including overhead wire electrification, battery-powered EVs, and

hydrogen fuel cell. For single occupancy vehicles, California wants to promote the wide adoption plug-in EVs and hydrogen fuel cell EVs. For trucking freight, California will invest resources into biodiesel and electric semi-trucks (Caltrans, 2018).

In Caltrans' Sustainable Freight Action Plan, they develop policies and goals to modernize California's freight rail and trucking infrastructure. California is a major entry point for international trade in America with the ports of Los Angeles and Long Beach being the busiest ports in the United States (Caltrans, 2016). In California, freight and industrial jobs make up about one third of California's jobs and economy (Caltrans, 2016). Freight pollution and air quality issues are a major problem around ports and intermodal terminals, which can hurt nearby communities (Caltrans, 2016). To modernize freight infrastructure and reduce the negative impact of freight, Governor Brown signed Executive Order B-32-15, which requires freight transportation to move to zero and near-zero emission technology (Caltrans, 2016).

Implementing policies related to this executive order will require working with local actors like MPOs and doing PPPs (Caltrans, 2016). PPPs related to investing in expanding freight rail and trucking capacity are a major part of the plan (Caltrans, 2016). Examples of freight modernization include using automated cranes, expanding rail capacity, and investing in semi-autonomous and autonomous technology to adopt platooning for trucking (Caltrans, 2016).

In what can be considered best practice, the Port of Long Beach (POLB) and the adjoining Port of Los Angeles (POLA) work together to create an unusual partnership. While the two neighbors are competitors and combined rank as the world's sixth busiest port complex, they are a multijurisdictional entity of astounding coordination. The

cooperating agencies include the U.S. Coast Guard, Customs and Border Protection, state and federal Homeland Security offices, the Long Beach and Los Angeles Police Departments, and the private Harbor Patrol of each Port.

Understandably, the ports benefit from large public and private investment. They utilize state of the art facilities, designed with security in mind and built to support communication and deployment. Because the ports share resources and coordinate, there is redundancy and multiple sources for documentation. Additionally, both POLB and POLA are continuing to build out cyber security infrastructure and engage in a national conversation about comprehensive supply chain security and resiliency (POLB, n. d.).

An additional four best practices come from Pennsylvania, Indiana, Virginia, and New York for the global issues broad source of risk (Table 27). These were selected based on their unity in targeting the management of governmental data and communication. Pennsylvania's Risk-based Multi-Factor Authentication (RBMFA) combats and manages outside access to administrative sites (NASCIO, 2017c). Indiana's Information Sharing and Analysis Center (IN-ISAC) was established to grow efficiency of governmental cybersecurity, in an effort to push the cost down and further invest in security measures (NASCIO, 2017a). Virginia's Information Technologies Agency (VITA) serves to protect public facing governmental websites, the first line of administrative communication (NASCIO, 2016). New York's Risk and Remediation Tracking System works to document vulnerabilities and assess web inventory, which supports cybersecurity and operational initiatives (NASCIO, 2017b).

Table 27. Best Practices in State Government Cybersecurity				
Location	Pennsylvania	Indiana	Virginia	New York
Project Name	Risk-based Multifactor Authentication (NASCIO, 2017c)	Indiana Information Sharing and Analysis Center (NASCIO, 2017a)	Virginia Information Technologies Agency (VITA) Web Application Vulnerability Scanning Program (NASCIO, 2016)	New York State Risk and Remediation Tracking System (NASCIO, 2017b)
Purpose	Risk-based Multi-Factor Authentication (RBMFA) enterprise service for the hosting of government services and data in the cloud. The Risk Authentication system evaluates the user and his or her access attempt based on several criteria.	Indiana Information Sharing and Analysis Center (IN-ISAC) was created in 2015 to reduce the overall cost of cybersecurity through the centralization of resources, leveraging of large-scale purchasing, improved prevention efforts and faster containment of threats.	Effective July 1, 2016, the Virginia Information Technologies Agency (VITA) revised its security standard to require scanning of public-facing websites and systems every 90 days. VITA now provides a web application with vulnerability scan service.	The Risk and Remediation Tracking System facilitates efficient and effective security risk assessments through comprehensive risk assessment processes. It supports collection and validation of critical application asset inventory data and documentation needed to support security and other operational objectives.

Recommendations

Given the risks associated with Florida's changing composition and demographics of the population, FDOT should develop a range of realistic growth scenarios, including plausible combinations of growth forecasts and different spatial distributions to create a foundation for other planning efforts. The current FTP Vision Plan includes five different scenarios, including Return to Historic Growth, Rural

Rediscovery, Global Trade Hub, Innovation Hub, and Risks on the Horizon. While the scenarios provide diverse assumptions about the demographic and employment characteristics of the state, the spatial distribution of the population is not as well represented in those models. Most of the population growth in the state continues to take place in already developed coastal areas that are vulnerable to the impacts of sea level rise. As such, the models need to adequately represent where growth is likely to take place so that the FDOT and regional and local planners can more accurately project and target where and why we need more multimodal transportation options.

The scenarios could include the county categorization that TxDOT uses in their scenarios, or it could use BEBR's population projections to develop their scenarios. Texas's categorization system is especially useful in rural or underdeveloped counties, but its "zero migration' scenario is not realistic for Florida; since 2010, 90% of Florida's growth has been due to net migration. For Florida, a larger categorization system could be beneficial when highlighting specific areas of vulnerabilities or opportunities where growth could be welcome. Scenarios developed by two Florida organizations – 1000 Friends of Florida and the East Central Florida Regional Planning Council – provide examples of how scenarios might be developed for the Florida context. Because the high and low forecasts are rather extreme, we would recommend that FDOT develop three scenarios with the BEBR data: (1) the medium forecast, (2) an average of medium and low, and (3) an average of medium and high. Additionally, FDOT should conduct additional research and develop scenarios that address the impacts of sea level rise on Florida. Such a study would consider when coastal populations will be affected, when

these populations would move, and whether they would move further inland or leave Florida entirely.

Once Florida has developed more realistic scenarios, they should, like Texas and California, proactively plan to adopt a multimodal corridor planning process. Such a process would provide more transportation options for the growing population that does not drive, including older adults, new immigrants and other persons who do not drive due to cognitive and physical limitations. This multimodal planning process could be modeled after the guidance developed in District 5 or it could include elements, such as those in the California, Texas and other states.

In addition, the state will need to determine where the projected increases in the population of older adults will occur so that these transportation services are accessible to this cohort. The Florida Safe Mobility for Life Program is working to address the transportation needs of this cohort but we need to more adequately plan for them in the long-term because of the significant increase in population over age 80, which is projected to increase to over 2.7 million by 2045 (BEBR, 2019). A few Florida communities have explored PPPs with TNCs to provide for the transportation needs of older adults (Leistner & Steiner, 2017). Such partnerships present challenges because TNC drivers may not provide door-to-door service or be trained to handle wheelchairs, walkers and other mobility assistive devices. We recommend FDOT partner with regional and local transportation agencies and organizations working with older adults to examine potential PPP's that could provide these services through various subsidies available through existing programs.

Furthermore, it is recommended that public transit systems provide additional signage and other methods of assistance for travelers with barriers to transportation, due to the increasing language barriers for many residents and tourists. Similarly, the FDOT should provide incentives for start-ups that provide these services to initiate a private sector response to the cultural shift in parallel to that of the public sector. In addition to addressing the older adult population, the same steps should be taken to provide safe, accessible transportation options for other vulnerable populations, such as those with cognitive or physical limitations.

When planning for the uncertainties and vulnerabilities associated with population and demographic change, we must think of how to best support these vulnerable populations that may not have the same travel flexibility as most of the population. We must also consider how a growing population will impact our infrastructure and the potential this holds for us to incorporate innovative technology and active transportation around the state of Florida.

We recommend that the FDOT explore additional options for providing and funding public transit and other mobility options for residents of the state. As is clearly documented in the current FTP, the needs of residents vary depending upon where they live. Nonetheless, the FDOT should explore the use of PPPs, such as TNCs, to increase accessibility to public transit and to provide transportation services to meet Florida's diverse population. We also recommend that the state adopt additional revenue generation based upon user fees. While the state has a well-developed network of toll roads, the use of VMT-based user fees would more accurately represent the impact of vehicles on roadways. A VMT-based system of user fees would include

all users of the road irrespective of where they travel and the fuel efficiency of their vehicle. Such a system would include drivers of vehicles that use alternative fuel sources. In the alternative, we recommend that Florida adopt statewide taxation policies on alternative fuel sources within the transportation sector to supplement the reduced revenue generation of fuel taxes.

We recommend that Florida implement various policy elements from other states' LRTPs. First, Florida should implement an interactive tool such as Texas's and Oregon's, which allow stakeholders and the public to evaluate the trade-offs between future scenarios. Second, Florida should consider finding other sources of revenue for the transportation system, as mentioned above. We recognize that legislators are hesitant to raise taxes on residents of the state. At the same time, the state needs to consider innovative revenue sources for the transportation system. Florida should consider managing revenue sources and implementing revenue enhancements like the state of Washington, such as the transportation benefit district, additional local fuel taxes, and street maintenance utilities. These changes would help generate revenues that can be used for infrastructure maintenance and public transit. Further, Florida should consider taking additional steps against the decline in purchasing power of the fuel tax revenue like Pennsylvania. Because Florida's economy is dependent on tourism and freight movement like Georgia, the state should consider implementing a hotel/motel nightly fee and heavy vehicle annual impact fee as a source of funding.

The examples provided above show a few of the options that the state has to generate additional revenues for their transportation system. The FHWA Center for Innovative Finance Support (FHWA, n. d.) and the National Conference of State

Legislatures (NCSL) provide additional resources about innovative sources of revenue on their websites. The Center for Innovative Finance Support has a website that presents information and examples of projects that have used innovative finance techniques in the following categories: PPPs, alternative project delivery, project finance, tolling and pricing, and value capture (FHWA, n. d.). The NCSL monitors legislation that states have introduced and passed on an ongoing basis and they complete special studies on what is happening in states. In 2011, in collaboration with the American Association of State Highway and Transportation Officials (AASHTO) Center for Excellence in Project Finance, they completed a review of state legislatures and departments of transportation in the areas of transportation governance and finance (NCSL, 2011). In that report they summarize the state-by-state revenue sources for roads, bridges, rail and transit from the following sources: fuel taxes; sales taxes on gasoline and diesel; vehicle registration, license or title fee; vehicle or truck weight fees; traffic camera fees; tolls; general fund; interest income; and other sources (NCSL, 2011; p. 24-28). They also identify innovative finance mechanisms that states can use (Table 28). We recommend that FDOT research the types of revenues that other states are collecting to identify additional potential sources of revenue.

Table 28. Innovative Finance Mechanisms for State Departments of Transportation (NCSL, 2011).

Table 7. Transportation Finance Mechanisms

State Bonding and Debt Instruments
- Revenue Bonds
- General Obligation Bonds
- Hybrid Bonds

Public-Private Partnerships
- Pass-Through Tolls/Shadow Tolling
- Availability Payments
- Design-Build-Finance-[Operate]-[Maintain] Delivery Models
- Build-[Own]-Operate-Transfer and Build-Transfer-Operate Delivery Models
- Long-Term Lease Concessions

Federal Debt Financing Tools
- Grant Anticipation Revenue Vehicles (GARVEEs)
- Private Activity Bonds (PABs)
- Build America Bonds (BABs)

Federal Credit Assistance Tools
- Transportation Infrastructure Finance and Innovation Act (TIFIA)
- State Infrastructure Banks (SIBs)
- ection 129 Loans

Federal-Aid Fund Management Tools
- Advance Construction (AC) and Partial Conversion of Advance Construction (PCAC)
- Federal-Aid Matching Strategies
  - Flexible Match
  - Tapered Match
  - Toll Credits (Soft Match)
  - Program Match
  - Third-Party Donations
  - Using Other Federal Funds as Match

Other Innovative Finance Mechanisms
- Non-Federal Bonding and Debt Instruments
- Value Capture Arrangements such as Tax Increment Financing (TIF)

Sources: AASHTO Center for Excellence in Project Finance, 2008; Federal Highway Administration (FHWA) Office of Innovative Program Delivery, 2010; and Rall, Reed and Farber, 2010.

Each environmental risk poses a high level of vulnerability in the mid-to-long term (see Table 11) and each should be addressed in future planning processes. To address these risks, the following section provides recommendations for comprehensive statewide adaptation planning, sustainability measures based on industry standards, and updates to current infrastructure to address flooding.

To address sea level rise and the associated risks, FDOT should consider adopting a comprehensive strategic planning approach, similar to Louisiana's CPRA. Florida can adapt the CPRA's approach by completing a statewide assessment of Florida's transportation vulnerability and appropriating funds to address specific vulnerabilities. They should also continue to incorporate the FHWA tools and resources – vulnerability assessment framework, sensitivity matrix, and the CMIP Climate Data Processing Tool – into routine transportation planning practice at the state, regional and local level. FDOT has already made progress towards this approach. FDOT has funded the University of Florida's GeoPlan Center to map localized sea level rise projections for the entire state and develop an interactive tool for evaluating the potential impacts to the transportation system. FDOT also recently funded a project to look at the vulnerability of the state's most critical transportation assets, the Strategic Intermodal System. However, additional action is needed to integrate the vulnerability assessments into a comprehensive statewide master plan. Although CPRA's adaptation plans were not created in conjunction with Louisiana's DOT, the plans were framed through a transportation lens for easier implementation by them.

FDOT should consider adding requirements and funding for adaptation strategies for new infrastructure projects located in areas vulnerable to permanent flooding from sea level rise and temporary flooding from increases in heavy precipitation events, storm surge, and hurricanes. Adaptation strategies will vary depending on the local geography and specific risk but include measures such as hard armoring (sea walls), soft armoring (living shorelines), raising roads, and updates to stormwater infrastructure. Green infrastructure also offers many options for flood reduction, including permeable

pavement, retention ponds, and green stormwater infrastructure. FDOT can promote and fund the use of these adaptation strategies to combat the risks related to sea level rise and flooding.

Since the transportation sector is the leading cause of GHG pollution, FDOT should take strides to reduce emissions. Some DOTs have a sustainability element in their LRTPs, including the DDOT and Caltrans. DDOT's sustainability and livability element ensures that the environment plays an important role in their vision for a sustainable transportation system. Additionally, Florida can follow DDOT's inclusion of urban forestry in the LRTP to reduce the negative effects of increasing temperatures. Similarly, Florida can look to California's LRTPs, which is based on Triple Bottom Line sustainability; their approach on emissions standards, their system of testing and taxing vehicles that do not meet their guidelines and setting air quality goals for the entire state. These strategies can all be adapted to meet Florida's specific goals and objectives for a sustainable future.

Additionally, to further prepare for all environmental risks, the state should consider a statewide vulnerability assessment to evaluate the risks to all sectors, including transportation. While some local governments have already begun and completed community vulnerability and risk assessments, it is important to establish a precedence at the state level that can further vulnerability assessments across the state. The difficulties of this process can be offset by leveraging existing research and vulnerability assessments that have already been completed at the local level. As mentioned in the best practices section, the New South Wales guide to IRVA, with its assessment of vulnerability in financial capital, human capital, social capital, natural

capital, and physical capital, can be a useful tool to assess regional vulnerability to climate change.

Without an unexpected shock, personal income is expected to incrementally increase in the near and long term. Therefore, it is anticipated that congestion, VMT, and emissions will continue to present a challenge in transportation planning. With increased travel to and within the state stemming from increased personal income, we recommend that the state consider multimodal corridor planning to increase the capacity of existing corridors or alternative parallel corridors to reduce the stress of corridors at or near capacity. As is discussed above, FDOT should more actively plan multimodal corridors like other states. Enhanced multimodal corridors would work with state efforts to attract tertiary and quaternary labor pools, whose members emphasize quality of life and transportation choice. This is especially true for urban Millennials who prefer more multimodal and less automobile dominant modes of transportation.

To attract this cohort to Florida, it is recommended that the FDOT plan for a more multimodal and intermodal systems and support their preferred choice of modes. Incorporating all modes into the transportation system is a necessity if we are to support mobility in the SoFlo megaregion. The State makes tradeoffs between individual modes on an ongoing basis. However, as Florida continues to face revenue shortfalls and aging infrastructure, we need to recognize the importance of planning a multimodal transportation system that supports people of all incomes and transportation needs. An increase in per capita personal income provides an ampler tax base for the potential to elicit new streams of revenue. As such, we recommend that the state address the influence that personal income has on travel behavior within and to the state.

To address these risks, the FDOT should use the framework outlined in the FHWA white paper (see McCoy, Andrew, Glynn & Lyons, 2018) to integrate technology into multimodal transportation planning. While the white paper addresses shared mobility, the emerging practice and strategies – data access and sharing, regulating use of public infrastructure, operational partnerships, integrating shared mobility into modeling and forecasting – are also applicable to other areas of technology, such as AVs and CAVs. The technology of many parts of the transportation system – the right-of-way, the vehicle, the energy source, the role of the public and private sector and the funding system – are all changing at an increasing pace.

In this environment, the FDOT needs to plan for the technology at the state level while providing a framework for regional and local governments and their transportation agencies to respond to these changes. It is recommended that municipalities engage in early efforts of PPPs with advancing technology industries that dictate the type of data generated, access to it and use of it. Furthermore, in these partnerships it is essential for the municipalities to negotiate the data sharing aspect prior to the inception of these partnerships, in order to maintain or better the public sector's understanding of travel behavior and the continuous influence that advancing transportation technologies have on it.

As these partnerships are currently based on ride sharing applications such as Uber and Lyft, the current data generation is largely limited to single occupancy ride hailing trips that are typically unimodal. However, through the incorporation of multimodal integration, as well as connected vehicles and infrastructure, data generation will expand to include multimodal trips, and V2V and V2I communications,

resulting in massive amounts of data that can better inform planners on the travel dynamics of people and goods.

Additionally, regulations, such as licensing, will need to be coordinated with the transition towards fully driverless vehicles, specifically in regards to the transition of operational control. This is of particular importance as having the ability to take control at will is a factor in adoption and transition towards autonomy, with 94.5% of drivers still wanting the potential to have steering, gas, and brake pedal control (Schoettle & Sivak, 2016). However, requiring AV licensure poses a barrier for adoption and deployment, especially as temporal regulations scale vertically through the levels of government. For example, cities will be tasked with regulating autonomous vehicle networks and operations until state regulations step in (Bliss, 2017), which will be further regulated at the federal level. Thus, vertical coordination of policies and regulations by the state DOT regarding AVs, CVs, and CAVs will be fundamental in facilitating the effective operation of these vehicles, especially in the context of finding a regulatory balance. This is of particular importance, as the deployment of these vehicles will require shifts in responsibility and liability of operations between the public and private sectors and will require federal action or delegation of authority to the states (Taeihagh & Lim, 2018).

In addition to the issues of data sharing, the compatibility with current infrastructure is also a risk for the future of the transportation system, with the establishment of autonomous vehicles and connected vehicles on the roadways. For example, if autonomous vehicles are to be deployed without further connectivity to infrastructure and other vehicles, their introduction into the transportation system could result in decreased levels of safety and elevated safety concerns. Thus, it highly

recommended to ensure that infrastructure advancements occur in tandem with the deployment of advancing transportation technologies, like that of automation and connectivity.

It is further recommended that policies instill this timeline of deployment at the state level to avoid any unseemly issues stemming from the premature incorporation of these vehicles into the transportation network. The rationale for the state level approach to automation is to ensure that there is standardization across the state for the spatial deployments and utilities of these vehicles. It is also essential for there to be standardization of licensure for the operation of these vehicles. Lastly, the standardization of V2V and V2I connectivity will need to be promoted through the state level to ensure continuity throughout Florida. Furthermore, the state level is better equipped to inform, prepare, and communicate with the public about the presence and uses of these vehicles, as well as test for any necessary licensure.

Thus, it is in the best interest of the public sector to have vehicle connectivity parallel autonomy in progression through the transitional stages towards fully CAVs. In fact, too early of adoption and deployment can disrupt and undermine the efficiency and safety of the transportation system. Therefore, it is recommended that the public sector progressively act to develop policies that will attract these technologies while proactively and strategically controlling their deployments, as to enable the progression of autonomy and connectivity to occur in parallel with each other towards a fully connected and autonomous network.

Thus, to address the growing risks of transitioning towards an electric based transportation system, it is highly recommended to closely monitor the adoption trends

of EVs for consumers within the state as well as those traveling to the state. It is also highly recommended that the state begin to incentivize the construction of electricity supply stations within current gas station infrastructure to minimize the infrastructure-based transition of changing energy choices. Additionally, the monitoring of EV trends within the state needs to occur in conjunction with the monitoring of charging trends to avoid reaching maximum capacity of the current electric grid. By dually monitoring the adoption of EVs and the capacity of the electric grid, the state can avoid electricity blackouts, which would be extraordinarily detrimental to the economic competitiveness and mobility of the state.

California's policies and goals may be grand in scale but many could be adapted to Florida's Transportation Plan to plan to reduce technology risks. Adopting a plan to convert transportation to zero or near zero carbon technology would strengthen the FDOT's energy conservation and environmental goals (FDOT, 2015b). Improving corridors related to interregional passenger and freight travel is a major component of the FTP (FDOT, 2015b). California's policies of maximizing current rail corridors through investing in capacity improvements would make it possible to convert some intercity trips from single occupancy vehicles to passenger rail (Caltrans, 2018). For safety and capacity improvements to our current road network, investing in the infrastructure to support semi-autonomous vehicles AVs, and CAVs will be necessary (Caltrans, 2016). Caltrans' multimodal goals with creating an integrated transportation system would be important to adopt if the FDOT wants to reduce the risks related to having a disconnected local and intercity transit network (Caltrans, 2018).

Global security is often reflected in international diplomacy because it is directly related to trade and tourism. Florida's investment in maritime and aviation transportation is tied to foreign affairs. Airport security is highly regulated by the TSA and the USDHS. While these agencies in addition to others such as the United States Coast Guard, guide seaport security, PPPs also have an integral role to play. It is highly recommended that Florida further take advantage of its megaregion by bolstering the security of its airports and seaports through an extensive vertical and horizontal collaboration of various stakeholder agencies that resembles the uniquely beneficial partnership expressed in the best practices section between POLB and POLA in California.

As observed in the selected LRTPs of this research and in the seaport best practice, improving security practices, providing funding for cybersecurity programs and initiatives, and promoting workforce training are essential to preparing for cybersecurity. The reality is that at this time, these factors have not yet been realized. As of October2018, 36 states, D.C. and Puerto Rico introduced or considered more than 265 bills or resolutions related to cybersecurity during the year, but only eight of these bills were in Florida and only three passed. Further, only four bills in 2018 related to cybersecurity for AVs and CAVs, and most of those were related to the testing phase. Yet, while the development of cybersecurity programs is still in the early phases and, as shown above, there are some examples of good cybersecurity practice at the state level.

While the approaches towards moderating risks from Florida's connection to the global economy are set, the cited examples of best practices in cybersecurity are

specific and require a system of data management and security staff to be established prior to each program (Table 27). Florida currently has an Agency for State Technology, but the funding, visibility, and influence appears to be in the initial phases (FDMS, 2018). FDOT has created an Office of Transportation Technology that “prioritizes all technology projects ensuring enterprise coordination and management of technology and technology resources that directly deliver the core mission of the department. This unit's resources bolster safety and connectivity on Florida roadways by aligning technology and data; automating services; creating enterprise data and technology standards; and enhancing cyber security, thereby mitigating risks resulting from emerging technologies” (FDOT, n. d.). FDOT might consider how the initial phases of the networks started and what it will take to grow the security network. This is an area for further research.

The U.S. applies a top-down approach when it comes to national security. Hence, FDOT and other transportation agencies must practice in accordance with the guidelines, rules, and framework established at the national level. This is not research to identify those regulations, but to identify how FDOT can implement the national approach to security at a state or local level. The USDHS is an agency to consider as an example of best practice in this regard. The USDHS seeks to guide the performance-based processes in transportation by modeling priorities based on national goals. Therefore, FDOT should theoretically use national goals from legislative and administrative planning, reconcile the priorities for the specific environment, apply the priorities using the resources available, and therefore support the top-down approach. The USDHS identifies the key role of the transportation sector in the supply chain

operations that impact American life. It states as a goal; “Increase the ability of the transportation system to support homeland security and to safeguard the personal security of all users” (USDHS, 2018).

However, transportation agencies in Florida have not integrated risk or vulnerability assessments into their cyclical operations like some other sectors already have. There is an opportunity to learn from the annual assessment processes of other sectors through Homeland Security. Further research should be placed on the practical vulnerability assessments based on infrastructure and operational security, and this research should inform the next Florida LRTP. Further, the grant programs offered through the exemplary organization, the Surface Transportation Agency should be continued. The grants helped to fund and run cross-sector training, courses, and toolkits. This integral growth process should not be abandoned.

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