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Assessment of Planning Risks and Alternative Futures for the Florida Transportation Plan Update

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16. Abstract

Transportation is in a period of transformation as technology offers new ways to travel, shop, ship goods, and do business. Rapid technological changes, along with changing demographics, extreme weather events, fluctuating revenues, and other potential disruptors, have increased uncertainty in long-range transportation plans and forecasts. To address this uncertainty and reduce risk, planners are attempting to anticipate alternative futures and the potential timing of technological changes so they may adapt policy and investment strategies to offer value across a range of alternative futures.

This research project, entitled Assessment of Planning Risks and Alternative futures for the Florida Transportation Plan, involves faculty and graduate students from across the state of Florida in interdisciplinary research to address planning risk and alternative futures that can inform the update of the Florida Transportation Plan (FTP). The 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.

The overarching goal of this research is to help FDOT understand how risk and uncertainty can be addressed in long-range transportation planning processes with a focus on the FTP Vision and Policy Elements. FDOT is particularly interested in exploring risk and uncertainty related to population and demographics, economy and revenue, technology and energy, environment and natural disasters, and broader global issues.

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1,000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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Executive Summary

Transportation is in a period of transformation as technology offers new ways to travel, shop, ship goods, and do business. Rapid technological changes, along with changing demographics, extreme weather events, fluctuating revenues, and other potential disruptors, have increased uncertainty in long range transportation plans and forecasts. To address this uncertainty and reduce risk, planners are attempting to anticipate alternative futures and the potential timing of technological changes so they may adapt policy and investment strategies to offer value across a range of alternative futures.

This study explores potential disruptive or extreme events that may affect the future of transportation in Florida. It aims to assist the Florida Department of Transportation (FDOT) in considering how risk and uncertainty can be addressed in the 2020 update of the Florida Transportation Plan (FTP) and subsequent planning efforts. The overarching goal of this research is to help FDOT understand how risk and uncertainty can be addressed in long range transportation planning processes, with a focus on the FTP Vision and Policy Elements. Research for this project was conducted in four tasks as documented in four technical memoranda.

- *Technical Memorandum 1: Identification of Potential Statewide Planning Risks* aimed to identify key drivers of change and uncertainty with the potential to affect the future of transportation planning in Florida, assets at risk to these factors, and impacts that could occur at varying levels of incident intensity.

- *Technical Memorandum 2: Identifying and Managing Potential Consequences of Statewide Planning Risks* explored synergies among identified drivers of change and uncertainty, potential consequences or "risk events" attributable to various uncertainties, the level of vulnerability to such consequences, the potential timing of such changes, and overall risks to advancement of statewide transportation planning goals.

- *Technical Memorandum 3: Planning Implications for Alternative futures* explored the planning implications of risk and uncertainty as they relate to the alternative futures presented in the FTP Vision Element and statewide planning goals and objectives in the FTP Policy Element. Graduate students and faculty in the University of South Florida (USF) Master of Urban and Regional Planning program developed this report.

- *Technical Memorandum 4: Implications of Risk with Regard to Long- and Short-term Planning and Project Implementation* addressed risk and uncertainty in project-level planning processes.

Key drivers of change and uncertainty and potential vulnerabilities are identified in Chapter 2 of the report for four general risk categories: population and demographics, economy and revenue, technology and energy, and environment and natural disasters. Broader global issues,

such as cybersecurity and safety, are also examined, as are assets at risk to these factors (not exclusive to transportation assets) and impacts that could occur at varying levels of incident intensity. A summary table of findings and observations relative to the interactions of these potential risks or uncertainties is provided in Appendix A. Highlights follow in the summary below.

1) Rapid Population Growth

   Florida is now the third-largest state in the U.S. Much of this growth has been due to migration into the state from other areas. Whether Florida will continue to grow at the same rate for the next fifty years is highly uncertain. If growth does continue at a steady pace, as forecasts suggest, the state could face significant challenges in accommodating future travel demand. The ability to accommodate this demand will be influenced by the effectiveness of future land use and transportation plans in curbing sprawl development and the provision of a broader range of mobility options in dense urban areas.

2) Urban and Coastal Preference

   The percentage of Floridians that reside in urban areas (91%) is increasing and Florida has more multi-family housing compared to the nation. If current trends continue, dense urban core areas with more multi-family housing could favor the use of public transportation and increase non-auto trips. Much of Florida's urban growth remains focused along the coast in areas vulnerable to storm surge and sea level rise. Continued intensification of urban growth in these areas could be hazardous, posing risks to both life and property. Location and housing preferences of Floridians may change as a result. For example, people may choose to live farther from the coast, causing increased development pressure in rural and fringe areas.

3) Aging Population

   Florida has a growing aging population and continues to be a popular destination for retirees. About 7.4 million Floridians are expected to be 65 or older by 2050. Past studies have documented that travel behavior varies by age. As people age and retire, trip making typically diminishes. One reason is the elimination of commute trips. However, economic conditions and career preferences are resulting in delayed retirement, and more adults are assuming caregiving roles, creating more travel demand.

4) Changing Lifestyles, Workforce, and Travel Behavior

   Millennials are delaying life milestones, such as marriage, getting a driver's license, and car ownership, and are continuing with higher education for a longer period compared to past generations. They are also more technology savvy and more likely to use transit or other modes than previous generations. The proportion of women in the labor force has also greatly expanded in recent decades, and the proportion of millennials versus baby boomers is also increasing. Yet as millennials take jobs and start families, they appear to be driving at the same level or even more than earlier generations. If this

persists, we could observe continued auto demand, increased need for safe and affordable alternatives to driving, growing demand for walkable places, and growing use of mobility as a service.

5) Erosion of User-Based Revenues

An important concern in transportation funding in the U.S. is a widening of the gap between transportation spending and user-based revenues. The erosion of user-based revenues is even more sobering when viewed in relation to vehicle miles of travel forecasts (Sorenson, 2013). Causes include escalation of right-of-way and construction costs, fuel-efficient vehicles, and gas taxes that are not adjusted for inflation. Alternative user-based revenue streams are being explored, such as tolls, mileage-based fees, value capture, and congestion pricing.

Current proposals for mileage-based user fees, for example, aim to collect revenue from all road users, including electric vehicles (EVs), bicycles, and transit, rather than strictly motor vehicle users. Many of the proposed revenue streams are regressive in their impacts on lower income people, raising equity concerns. In addition, government agencies are increasingly looking to the private sector to help fill the gap, leading to a growing private role in transportation, more complex business models, and pressure toward a “user pays” economy.

6) Growth in Freight and Deliveries

Freight transportation is an important part of the U.S. and Florida economy. Technology is changing how this sector operates and may evolve in the future. The global economy and demand for freight movement are leading to larger ships and trucks, and the recent explosion of e-commerce and same-day delivery of goods is causing truck traffic to increase dramatically. Automated and connected vehicles (AV/CV) and information and communications technology (ICT) could help with supply chain management, energy efficiency, and cost savings.

Uncertainties include the impact of freight growth on congestion and maintenance needs, how AV and other technologies could help, and shipment methods, especially for first/last mile deliveries. Deployment of AV- and truck-only lanes reducing delivery costs and improving safety, first/last mile delivery innovations (unmanned aerial vehicles; transportation network companies, or TNCs) and crowdsourcing of warehouse capacity are among the freight-related changes that could ensue.

7) Transportation Investment, Equity, and the Economy

Transportation and the economy are interrelated in a myriad of ways. A good transportation system benefits the economy and enhances access to jobs, services, and opportunities. Transportation-disadvantaged populations often rely on public transportation to meet daily needs. Yet agencies are often pressured to reduce such service in periods of economic decline, even as demand for ridership increases.

Conversely, transit ridership tends to decline as the economy improves or gas prices go down.

Uncertainties surrounding this topic include the degree to which transportation investments support the economy, how transit investments influence ridership, and the cost of transportation. Studies suggest that transit investment can fail to increase ridership in less dense areas or during periods of economic growth, transportation investments may or may not increase economic productivity and jobs, and lack of safe and affordable transportation options impedes access to opportunity.

8) Automated and Connected Vehicles (AV/CV)

The advent of automated and connected vehicles is among the more revolutionary changes in transportation. Florida is a leader in advancing AV/CV laws and testing. Many uncertainties surround AV/CV, including the timing of deployment and adoption, infrastructure needs, liability and insurance, cybersecurity, and impacts on mobility, safety, system capacity, privacy, parking, and land use.
A key question relates to the infrastructure needed to serve AV/CV and whether states will be able to cover these costs. The role of the private sector will likely need to increase in this regard.

9) Ridesourcing and Ridesharing

Advances in technology and abundant use of smartphones have enabled widespread use of ridesourcing (e.g., TNCs such as Uber and Lyft) and ridesharing (e.g., carshare, bikeshare, shared TNC, e-scooters, etc.). Ridesourcing can either complement transit or be its competitor. The ability to share transportation resources through carsharing, bikesharing, and other ridesharing services is leading to a "sharing economy." These services have the potential to reduce the number of vehicles on the road and transform personal mobility, particularly in urban areas.

Uncertainties associated with ridesourcing and ridesharing include their rate of expansion, as well as impacts on car ownership, transit use, walking, cycling, and congestion. These services could complement transit, but recent studies suggest that, more often than not, they compete with transit (as well as short walk and bike trips) and generate more car traffic. Nonetheless, these services, together with the advent of AV/CV/ICT, promise to support multimodal integration and improved urban mobility.

10) Alternative Fuels and Zero Emission Vehicles (ZEVs)

Use of electric vehicles (EVs) and charging infrastructure is increasing in the U.S. and Florida. In addition to an increase in personal EV ownership, the use of EVs in the transit industry is expected to grow even faster than for light-duty vehicles. Plausible forecasts suggest that by 2040, most buses will operate on electricity (Bloomberg New Energy Finance, 2018). The 2018 electric vehicle study by BloombergNEF predicts that: "The electrification of road transport will move into top gear in the second half of the 2020s,

thanks to tumbling battery costs and larger-scale manufacturing, with sales of electric cars racing to 28%, and those of electric buses to 84%, of their respective global markets by 2030."

Additionally, many diverse types of alternative fuels exist. Uncertainties include the potential of these fuels to replace or overtake petroleum, their impact on revenues, and availability of the appropriate infrastructure for their use. The use of these technologies in the future could lead to reduction in gas tax revenues and reduced or no emissions.

11) Other Technological Advances

Many other types of technology are emerging that can transform the future of transportation. Many questions surround how these different technologies will affect mobility, accessibility, safety, infrastructure, mode choice, and construction costs. For example, hyperloop technology is being developed in the U.S., and some preliminary corridors have been identified, including a link between Orlando and Miami. If successfully implemented, hyperloop technology would revolutionize long distance travel. Many uncertainties surround the future of this technology, including the viability of the technology, impacts on long distance travel modes, cost, and impacts on the built environment. Some other examples are:

- 3-D printing, which could decrease production and construction costs.
- UAVs and flying shuttles that could be applied to freight delivery and regional air travel.
- Blockchain applications in transportation that could greatly strengthen digital security.

12) Natural Hazards and Climate

Changes in the climate have led to growth in natural hazards, such as wildfires, extreme heat, sea level rise, hurricanes, tornadoes, intense storms, and flooding. Most of these effects are caused by a gradual planetary warming trend. Uncertainties related to this topic include: When and by how much will the sea level rise in Florida? What actions can we take to reduce greenhouse gas emissions from the transportation sector? Which locations will be affected and to what extent? To what degree might these unfortunate events disrupt the economy? How could we mitigate the impacts on coastal areas? What assets will be at greatest risk? Impacts of natural hazards and climate change include road and rail closures, airline delays and cancellations, weather related crashes and traffic disruptions, impediments to evacuation routes, limited construction activities, and economic disruption and decline.

Chapter 3 explores concepts and methods for evaluating and managing the potential consequences or "risk events" attributable to uncertainties or drivers of change. It begins by defining key concepts in the evaluation of risk, including likelihood, consequence/impact, level of vulnerability, and overall risk. Next, methods used to identify and categorize risks are examined, as well as strategies to manage consequences. Assets at risk (existing or planned) are

considered, as are opportunities that may emerge. The chapter concludes with a summary of key methods and tools in risk management from the literature. Chapter 4 operationalizes the findings in the form of a risk register tool.

Chapter 5 summarizes results of application of risk management tools and frameworks to the different alternative futures outlined in the FTP Vision Element and policies and objectives outlined in the FTP Policy Element. Chapter 6 then examines the FDOT project-level planning process and incorporates concepts from the research to integrate consideration of risk and uncertainty into project-level transportation planning in the form of a Project-Level Planning Risk Assessment Prototype.

Key conclusions and recommendations from the study are summarized below, together with supporting information as synthesized from the various chapters.

1) **Encourage resiliency by integrating adaptive processes, flexible consequence management strategies, and benchmarks/thresholds into long range planning processes.**

   Adaptive processes allow planning agencies to minimize risk and embrace uncertainty in long range transportation planning. With a feedback loop, the adaptive planning process provides opportunities to monitor and evaluate risks and assess the feasibility and effectiveness of planning decisions. For example, the Adaptive Decision-making (ADM) framework integrates an iterative cycle at every step or interval of the decision-making process. At each interval, decisions can be optimized based on evolving conditions and knowledge of future risks. The Project Risk Management (PRM) method is cyclical and requires new risks to be evaluated as they become apparent. The Adaptation Decision-Making Assessment Process (ADAP) provides built in opportunities for frequent reevaluation and adjustment as new information is acquired.

   Within the adaptive planning process, consequence management strategies can be identified that provide flexible options to address the consequences of identified risks. Decision trees are well suited for adaptive processes because they inherently provide opportunities for frequent reevaluation and adjustment as new information is acquired. Figure ES 1 shows a conceptual decision tree framework for adaptive project-level planning processes using concepts from ADM, ADAP, and PRM.

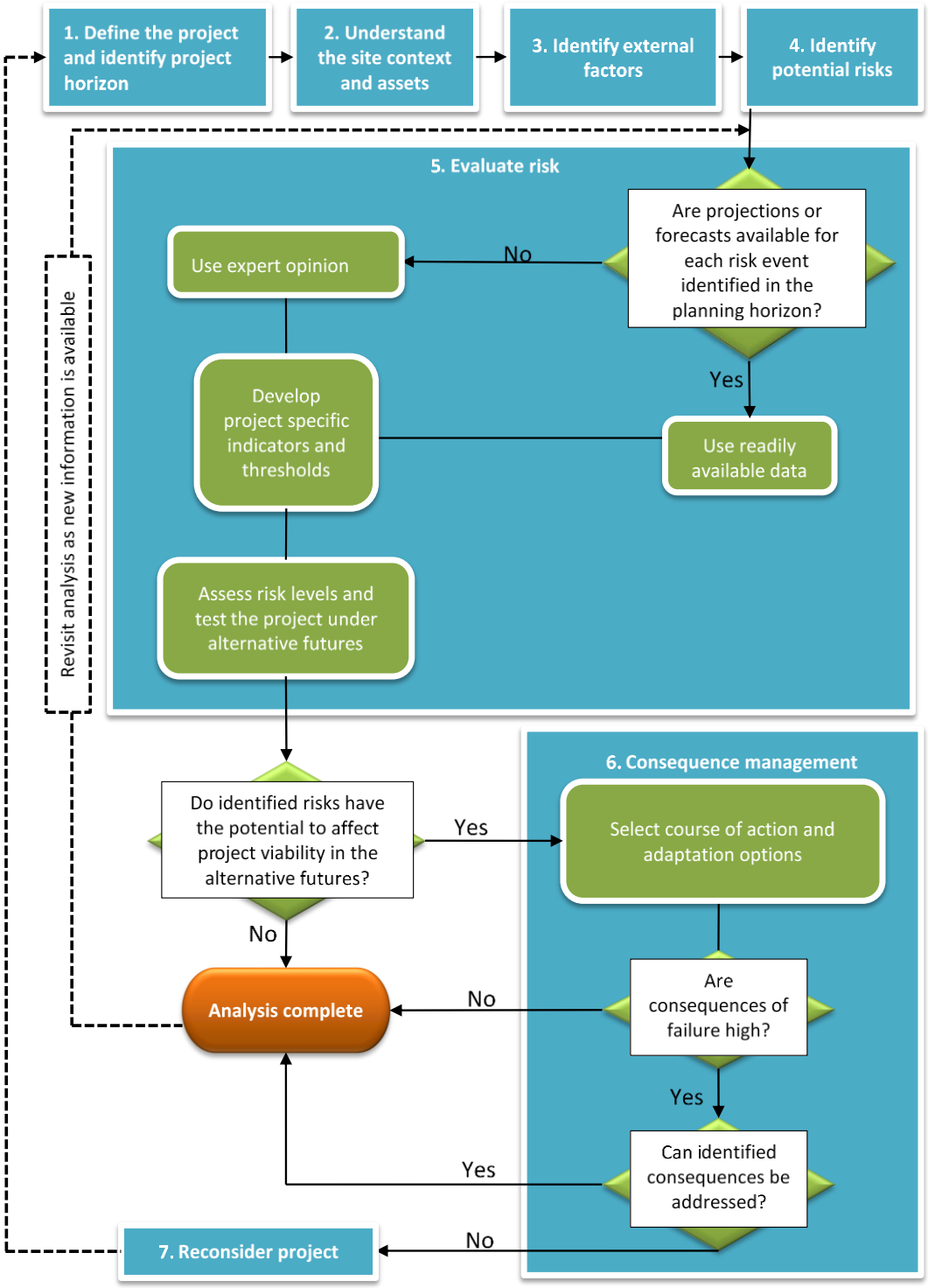

Figure ES 1. Project-level planning risk assessment process

Risk monitoring, a critical step in adaptive frameworks, requires analysis to be revisited as new information becomes available. Benchmarks and thresholds are developed for

short- and long-term project plans and referenced during this step and then revisited at logical phases of the planning and design process.

2) Use risk registers to identify potential risk events and assess risk level in the planning process.

A risk register is a comprehensive list that describes the characteristics of risks, such as the likelihood of occurrence, the impact or consequences, the root causes, affected objectives, and overall risk rating. Risk registers can also include risk triggers, risk responsibility, and mitigation strategies. This tool helps an agency to crystallize the potential risks associated with a given course of action.

Risk registers are easily integrated into existing planning processes and can be used in tandem with other risk identification and management tools. They are flexible in that they can be used extensively or for guidance in the risk management process, depending on an agency's specific needs. When used during stakeholder engagement, for example, risk registers can help stimulate meaningful discussions between participants and the facilitating agency.

The risk register in Table ES 1 is an example of how one might analyze risk in relation to statewide planning goals and objectives. Through a brainstorming process, specific risk events (consequences) are identified relative to areas of uncertainty. These risk events are then categorized based on their relevance to adopted statewide planning goals and objectives, as reflected in the FTP Vision and Policy Elements. Each risk event is further examined based on the likelihood of the risk occurring, magnitude of its potential consequences, and the level of vulnerability to experiencing those consequences using the formula:

Risk = Likelihood x Consequence x Vulnerability

Possible timeframes for each risk event are also identified, along with general consequence management strategies.

Table ES 1. Risk Register

	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
Goal 1: Safety and security for residents, visitors, and businesses	**Threats**							
	Hacking and cybersecurity threats to public and private transportation	4	4	5	80	E	Extreme Risk	Avoid
	New technology causes investment to be prematurely obsolete	4	4	5	80	E	Extreme Risk	Avoid
	Intensification of development in high hazard areas	5	4	4	80	C	Extreme Risk	Avoid
	Aging population causes surge in demand for safe mobility options	5	4	3	60	E	High Risk	Coordinate
	Wildfires disrupt major transportation routes and reduce visibility	4	3	4	48	U	Moderate Risk	Mitigate
	New technology systems perform unsafely or increase liability	3	5	3	45	U	Moderate Risk	Avoid
	Failure to evacuate vulnerable populations due to evacuation routes in high hazard areas	2	5	4	40	U	Moderate Risk	Coordinate
	Arterial flooding disrupts major transportation routes and systems	4	3	3	36	C	Moderate Risk	Mitigate
	Opportunities							
	Decrease in incidents caused by unsafe, distracted, and impaired driver and operator behavior							Enhance
	AV offers safe mobility for aging population, teenagers, and users with limited mobility							Share
	Enhanced real time data collection and reporting for safety, security incidents, and exposure							E...

3) Use a decision-making focus and driving forces to develop scenarios.

An important finding from our analysis is that the alternative futures as presented in the FDOT FTP Vision Element are not constructed based on specified external driving forces. The use of driving forces is essential for scenario construction to be useful for planning purposes. Without them, the planning implications of the alternative futures cannot be evaluated. Scenario development must be grounded in consideration of directional driving forces from which trends—however uncertain—can be projected and monitored in response to data and a desired future direction. It is unclear, therefore, how these futures can be used to guide planning and investment decisions or to address risk and uncertainty.

For the FTP update, FDOT should consider developing scenarios based on relevant trends and driving forces and a clear focus on the outcomes sought by decision-makers. These scenarios can then be used for specific decision-making applications, such as where infrastructure investments should be made or what type of investments should be prioritized.

Goals and objectives in the FTP Policy Element provide a logical starting point to identify the decision focus for Florida-specific scenarios. Driving forces may be external or organizational. External driving forces, which can include social, economic, environmental, and political forces, are relevant to the scenario, but outside of the

agency's control. Organizational driving forces are actions and general positions taken by the agency. These forces should be prioritized by the scenario team according to their level of predictability and importance in affecting the desired outcome. The driving forces identified through this research provide a starting point.

Once the driving forces are identified, scenario plots can be created to explain how driving forces interact and what effects they have on the decision-making focus. Table ES 2 is an example of four potential futures (scenarios) that might emerge from the linkages and directional flow of external and organizational forces.

Table ES 2. Alternative futures Revisited: Scenario Plot of External and Organizational Forces

Revisited Alternative future	**External Forces**	**Organizational Forces: Policy Framework/Funding**
Green Innovation	Transformative Growth	Sustainability and Equity
Green but Lean	Trend Growth	Sustainability and Equity
Commerce and Trade	Transformative Growth	Economic Efficiency
Status Quo	Trend Growth	Economic Efficiency

The next step for scenario development is to flesh out each scenario. Maack (2001) indicates that this should "incorporate lessons revealed by analysis of quantitative and qualitative data relevant to the assumptions underlying each scenario." The scenario matrix, shown in Figure ES 2, is provided as a conceptual example of how one might flesh out each of the potential futures (scenarios) shown in Table ES 2.

Once scenarios are developed, their content can be integrated into decision-making using the following steps:

1) Study scenario implications and lessons learned.
2) Choose indicators that help decision makers monitor and react to changes in the external environment or developments in the project.
3) Disseminate scenarios by refining them into easy-to-read language for use by implementing organizations.
4) Integrate scenario outcomes into daily procedures by changing the incentive system in an affected agency to move toward the goals formed based on the scenario analysis.

Scenario planning processes should integrate opportunities for monitoring and modification as new information becomes available. Furthermore, to ensure resiliency in Florida's transportation system, each scenario should account for natural disasters.

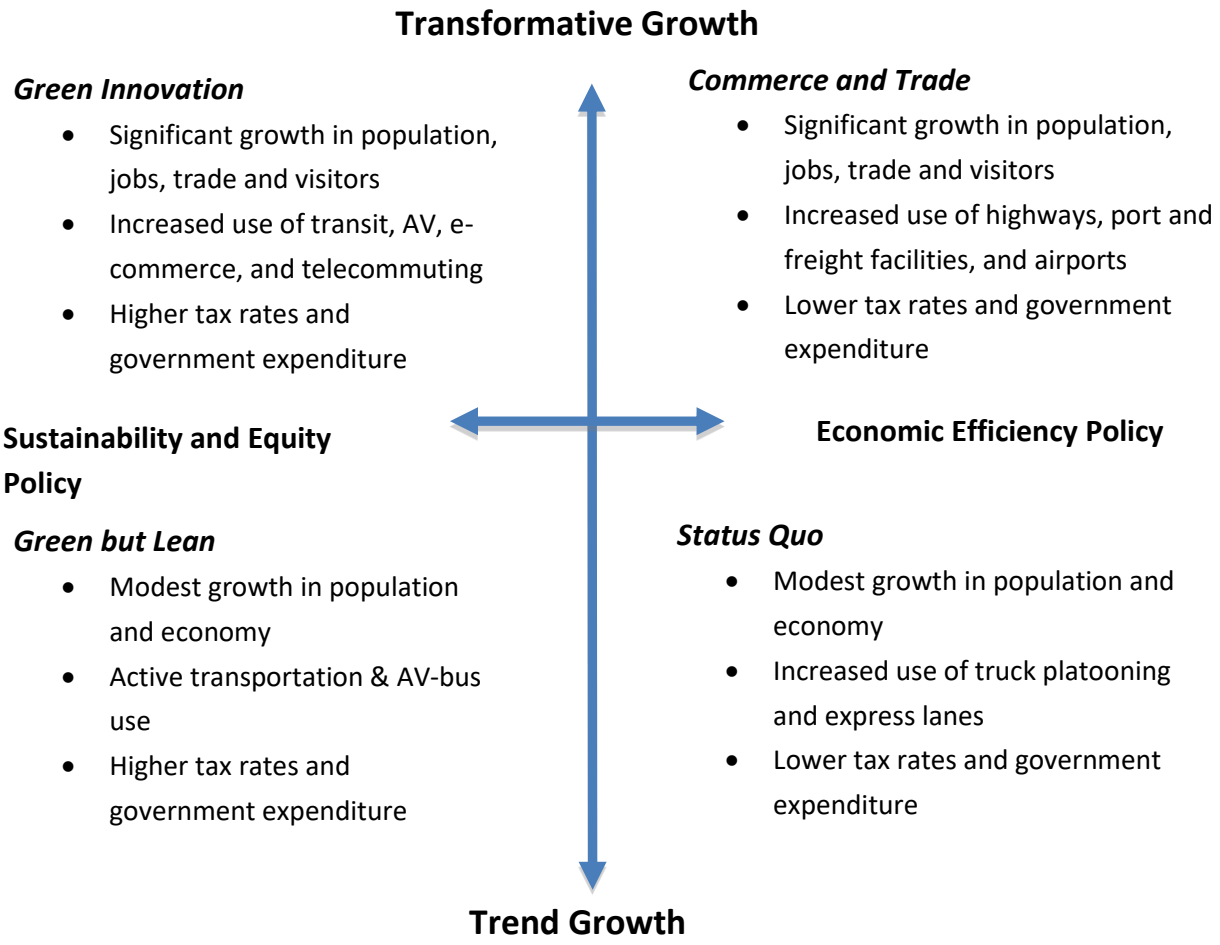

Figure ES 2. Alternative futures revisited: scenario matrix

The alternative futures generally predict two different overall growth paths: 1) one with high population and economic growth based largely on transformative leaps forward in technology (this general future prospect is referred to as *Transformative Growth*), and 2) a second that assumes more moderate growth where the economy and technology continue "on trend" growth, but without transformative shifts (referred to as *Trend Growth*).

In conclusion, threats and opportunities in an unknown future create risk and uncertainty in transportation planning. Projections and forecasts can provide some insight into future conditions, but with the ever-evolving nature of technology, the unpredictability of the environment caused by climate change, uncertainty regarding population and demographics, and increasingly diminished revenue sources, new ways to prepare for the future are needed. Research for this project attempts to define future risk and uncertainty in relation to long-range transportation planning in Florida. The products of this research are a set of existing and conceptual methods, frameworks, and tools to mitigate risk at various levels of planning.

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Chapter 1
Introduction

Transportation is in a period of transformation as technology offers new ways to travel, shop, ship goods, and do business. Rapid technological changes, along with changing demographics, extreme weather events, fluctuating revenues, and other potential disruptors, have increased uncertainty in long range transportation plans and forecasts. To address this uncertainty and reduce risk, planners are attempting to anticipate alternative futures and the potential timing of technological changes so they may adapt policy and investment strategies to offer value across a range of alternative futures.

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- *Technical Memorandum 4: Implications of Risk with Regard to Long- and Short-term Planning and Project Implementation* addressed risk and uncertainty in project-level planning processes.

This report summarizes the highlights of the research effort as it relates to the following:

- **Chapter 2: Drivers of Change and Uncertainty** – categorizes and describes risks with the potential to impact long-range transportation planning in Florida.

- **Chapter 3: Evaluating and Managing Consequences of Risk and Uncertainty** – identifies concepts, methods, and tools to evaluate and manage the consequences of risk and uncertainty.
- **Chapter 4: Risk Assessment Tools for Long Range Planning** – introduces three tools developed to assess risk in long range planning. Tools include a risk register tool, an asset screening tool, and an alternative future screening tool.
- **Chapter 5: Planning Implications**– presents a process to revisit the alternative futures using a decision focus and driving forces.
- **Chapter 6: Project-Level Transportation Planning** – addresses how risk and uncertainty influence the viability of projects in futures characterized by scenarios.
- **Chapter 7**: **Conclusions and Recommendations** – summarizes conclusions and provides a set of recommendations for FDOT's consideration as they proceed with the 2020 FTP update.

Chapter 2
Drivers of Change and Uncertainty

This chapter explores key drivers of change and uncertainty and potential vulnerabilities that stem from four general risk categories: population and demographics, economy and revenue, technology and energy, and environment and natural disasters. Broader global issues, such as cybersecurity and safety, are also examined as are assets at risk to these factors (not exclusive to transportation assets) and impacts that could occur at varying levels of incident intensity. The chapter concludes with a summary of overarching long-term issues facing Florida prepared by metropolitan planning organizations (MPOs). A summary table of findings and observations relative to the interactions of these potential risks or uncertainties is provided in Appendix A.

Population and Demographics

Rapid Population Growth

In 2015, Florida became the third largest state and continues to grow approximately twice as fast as the nation as a whole. Florida's 2017 population was estimated at 20,484,142. Table 1 shows BEBR's low, medium, and high projection series from 2020-2045, which demonstrates that Florida could gain as few as 4 million or as many as 10 million people in the next 27 years.

Table 1. Population Projections for Florida, 2020-2045.

	2020	2025	2030	2035	2040	2045
Low	20,889,600	22,026,300	22,890,500	23,553,900	24,063,200	24,466,400
Medium	21,526,500	23,061,900	24,357,000	25,485,600	26,492,000	27,423,600
High	22,152,200	24,075,600	25,790,600	27,374,200	28,870,500	30,327,400

Source: BEBR, 2017

Much of this growth has been due to migration into the state from other areas. In recent years (2011 through 2015), migration accounted for 86% of growth in Florida, with the balance attributable to natural population increases. Migration was split about equally between domestic migration and international immigration (Figure 2). This affects travel behavior among the labor force, as foreign-born workers tend to use transit at double the rate of native-born workers. Hispanic men had the highest workforce participation rates in the U.S. overall as of 2010, but acculturation may reduce public transit use among Hispanics as U.S. births, not immigration, will account for increases of this population in the future (Zmud et al., 2014). Hispanic birthrates may decrease in future generations but will still account for the largest share of total births by ethnicity.

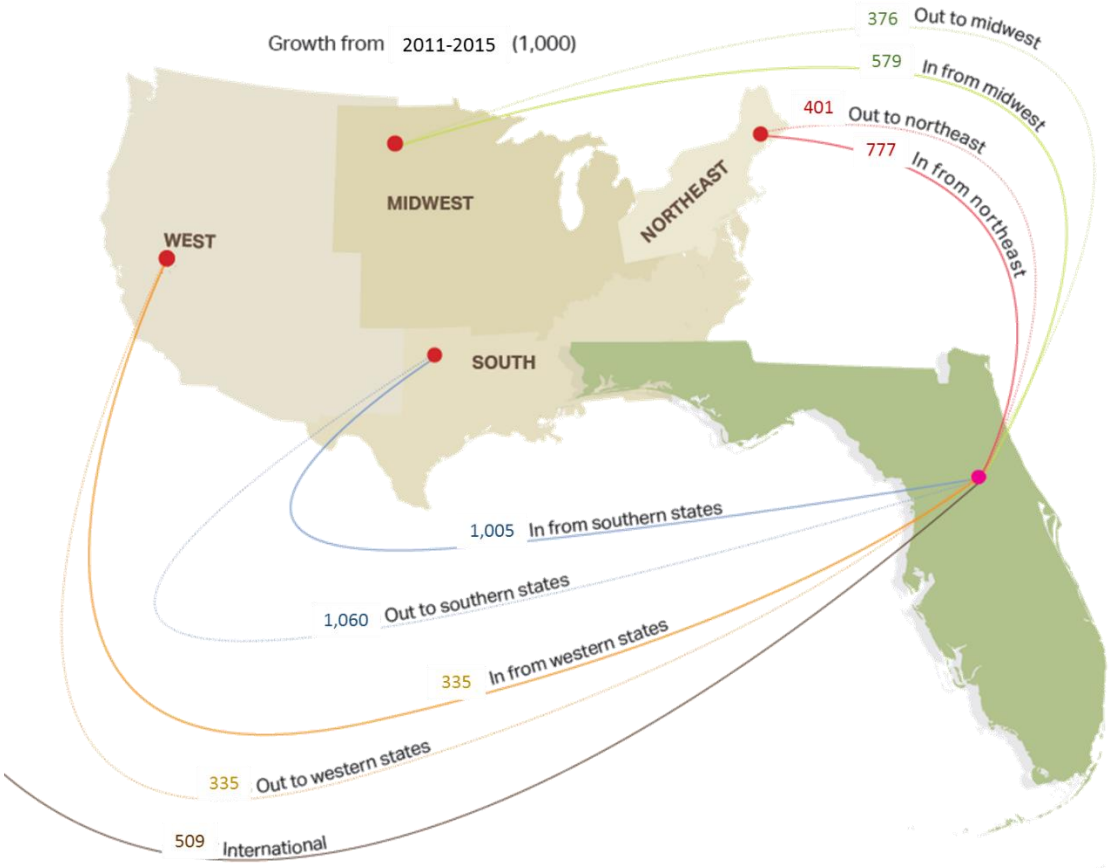


Figure 1. Florida's migration and immigration trends from 2011 to 2015.

Source: Data obtained from U.S. Census Bureau (n.d.)

Whether Florida will continue to grow at the same rate for the next fifty years is highly uncertain. If growth does continue at a steady pace, as forecasts suggest (Figure 1), the state could face significant challenges in accommodating future travel demand. The ability to accommodate this demand will be influenced by the effectiveness of future land use and transportation plans in curbing sprawl development and the provision of a broader range of mobility options in dense urban areas.

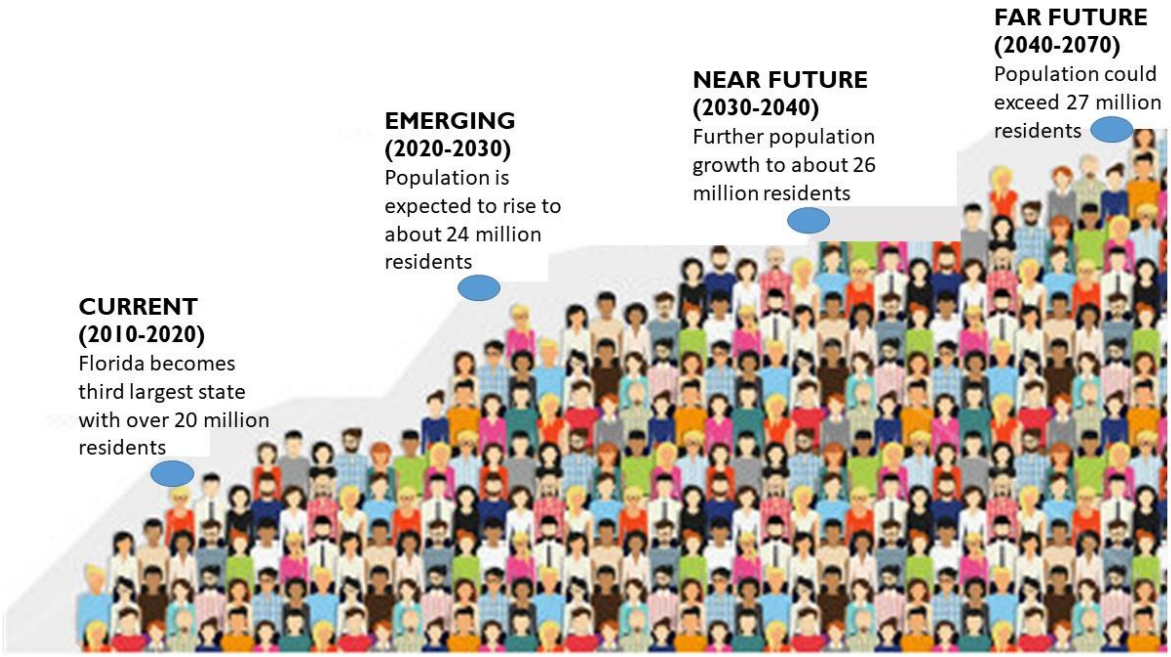


Figure 2. Florida population growth

Source: Data obtained from BEBR, 2017

Urban and Coastal Preference

Florida's overall density continues to increase and growth rates have been higher in and around major urban areas. Over 91% of Florida's population now resides in urban areas, with county population density varying from 3,400 persons per square mile in Pinellas County to only 10 persons per square mile in Liberty County. Figure 3 illustrates population density by county in Florida. Areas with the highest population density have more complex transportation systems and needs, whereas rural areas with low population density face challenges such as connecting a dispersed population to jobs, health care, and other services.

The number of multi-family housing units increased by over 84% in Florida from 2000 to 2014, while single-unit housing rose only 40%. In comparison, the U.S. as a whole witnessed a 15% increase in multi-family units and an 18% increase in single-unit housing structures. As of 2014, Florida had a lower share of single-unit detached housing and a higher share of multi-unit housing than the U.S. In addition, Florida continues to have larger shares of mobile homes than the country as a whole.

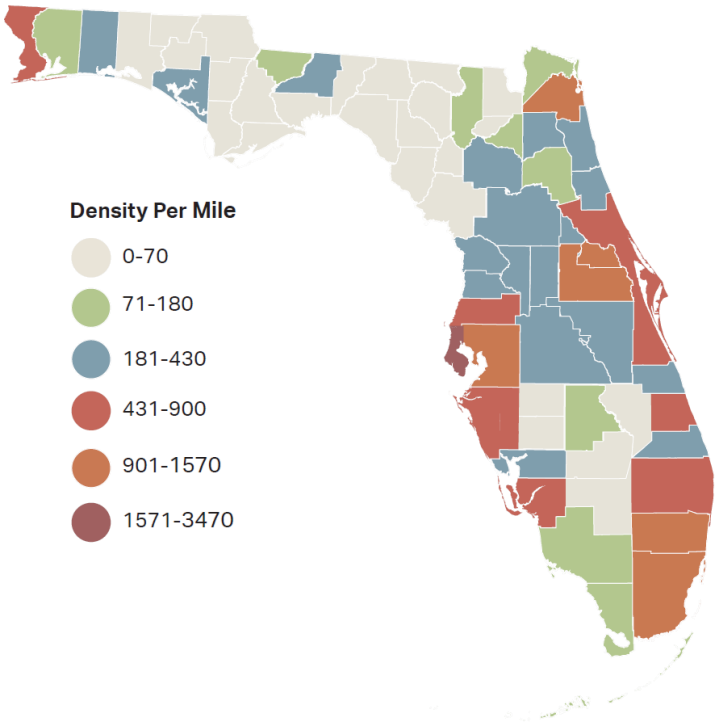


Figure 3. Population density in Florida.

Source: Data obtained from U.S. Census Bureau, 2010

If current trends continue, dense urban core areas with more multi-family housing could favor the use of public transportation and increase non-auto trips. However, much of Florida's urban growth remains focused along the coast in areas vulnerable to storm surge and sea level rise. Continued intensification of urban growth in these areas could be hazardous, posing risks to both life and property. Location and housing preferences of Floridians may change as a result. For example, people may choose to live farther from the coast, causing increased development pressure in rural and fringe areas.

A survey was conducted by the National Association of Realtors that offers insight into national transportation and residential/community preferences overall and by age cohort as of 2017. The survey found little change since 2015 about where people live, with most living detached homes in the suburbs with sidewalks, parks, and public transit nearby. Twenty percent of respondents who live in a traditional suburb would prefer to live in an attached home in a walkable community. These were likely to be part of the Silent Generation or Millennials with children at home. Millennials who said they wanted to live in the suburbs tended to change their preferences when commute time was introduced. Although Generation X preferred detached homes overall, 60% of all respondents reported that they would spend more on housing to get walkability, and more walkability was linked to greater neighborhood satisfaction. Sixty percent of those surveyed also said that they drive primarily because they have no other options where they live.

A preference for access to transit was found to be correlated with income – transit was more important to those making less than $50,000 a year – whereas a desire for walkability was not affected by income. The most inconsistent groups in this preferences survey included those who live in small towns, those who have kids at home, and those of Hispanic origin. These groups were split between wanting density and walkability, and wanting detached suburban homes.

Changing Lifestyles, Workforce, and Travel Behavior

Seven socio-demographic variables have been identified as key influences on US travel demand and travel behavior (Zmud et al., 2014):

- Age
- Race/ethnicity
- Acculturation
- Household structure
- Household income
- Workforce participation
- Residential location

The travel influences of age and race are among the most debated of these factors as they vary widely based on socio-economic and other considerations. Degree of acculturation contributes to racial and ethnic differences in travel behavior, and household structure often varies due to age, race, and acculturation of various groups. Trends in workforce participation and household income are linked to those three factors of age, race, and acculturation, as well. Residential location may be the most independent of the seven variables, but data shows varying conclusions about location choices by age with a particular focus on the millennial generation.

For this study, definitions of birth years by generation are taken from recent guidelines issued by the Pew Research Center (Dimock, 2018). These include the Silent Generation (1928-1945), Baby Boomers (1946-1964), Generation X (1965-1980), Millennials (1981-1996), and Generation Z (1997-present). Generation X (1965-1980) has been largely ignored in these kinds of predictions, and as Zmud et al. (2014) noted, this is a much smaller cohort than the Baby Boomers before them or the Millennials after.

Millennials are delaying life milestones, such as marriage, getting a drivers license, and car ownership, and are continuing with higher education for a longer period compared to past generations. They are also more technology savvy and more likely to use transit or other modes than previous generations. The proportion of women in the labor force has also greatly expanded in recent decades and the proportion of millennials versus baby boomers is also increasing (Figure 4). Yet as millennials take jobs and start families, they appear to be driving at the same level or even moreso than earlier generations. If this persists, we could observe:

- Continued auto demand.
- Increased need for safe and affordable alternatives to driving.
- Growing demand for walkable places.

- Growing use of mobility as a service.

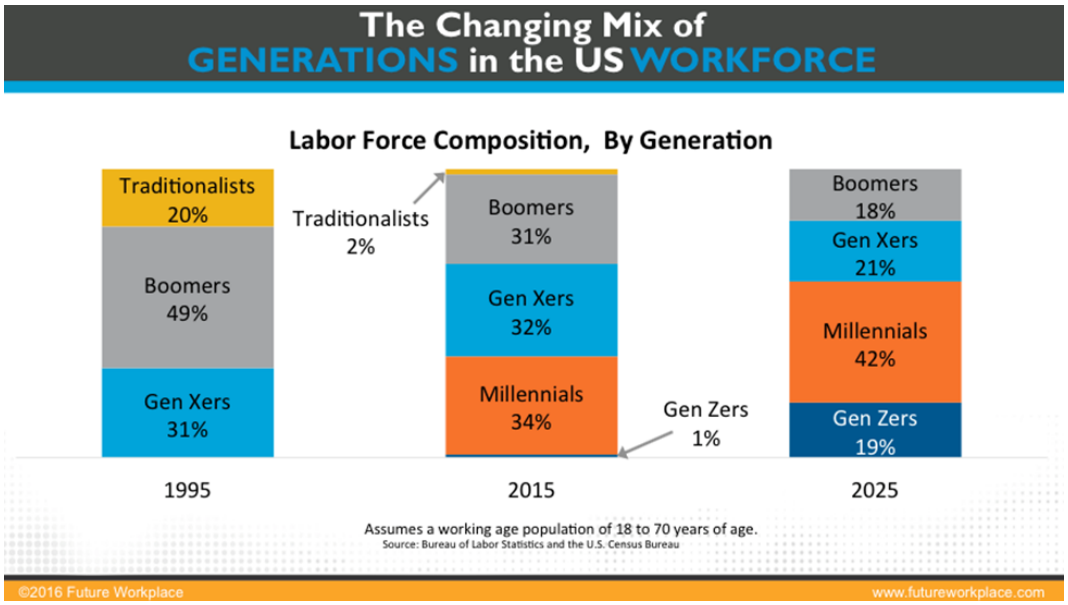


Figure 4. Workforce composition by generation.

Source: Meister et al., n.d.

Economic factors may be significantly more important than birth year when it comes to travel behavior. Youth unemployment doubled in the first decade of the new millennium, which corresponded to declining rates of travel in this group, but the effect of rising unemployment on declining travel was 32% greater for adults during the same time period (Blumenberg & Taylor, 2018). The higher proportion of youth in urban areas may be attributed to a difficult job market (and increased employment density), or perhaps to age-related (rather than birth-year related) interests such as being near nightlife and social activities.

Household size may also play a role in travel behavior; Baby Boomers are supporting more multigenerational households, and many Millennials moved back in with their Boomer parents during their early 20s or never left due to delays in the age of first marriage (Polzin et al., 2014; Zmud et al., 2014). However, Blumenberg and Taylor (2018), found no statistically significant interaction between living at home or being enrolled in higher education and travel behavior of young adults. Multigenerational households are also on the increase due to immigration, particularly among Asian and Hispanic immigrants (Zmud et al., 2014). Non-white Americans are disproportionately younger than the rest of the country, which may be contributing to higher rates of transit use and other travel behaviors that will dissipate as these young adults age (Brown et al., 2016).

People of Generation Z (1997-present) are mostly too young to drive or to have established travel behavior and preferences and are therefore left out of most analysis. One survey did conclude that 92% of Generation Z plans to own a car, and 72% would be willing to give up social media for a year to get a car (Shaheen et al., 2018). Most travel predictions based on age,

however, pertain to those sections of the population currently in their 50s and 60s as well as those in their 20s and 30s.

Aging Population

Florida has a growing aging population and continues to be a popular destination for retirees. The Bureau of Economic and Business Research (BEBR) reports that Boomers' numbers grew at a higher rate in Florida than in the rest of the U.S. due to in-migration from other states (Smith, 2015). By 2050, BEBR estimates that about 27% of the Florida population or about 7.4 million people will be 65 and older (Smith, 2015). This trend is illustrated in Figure 2.

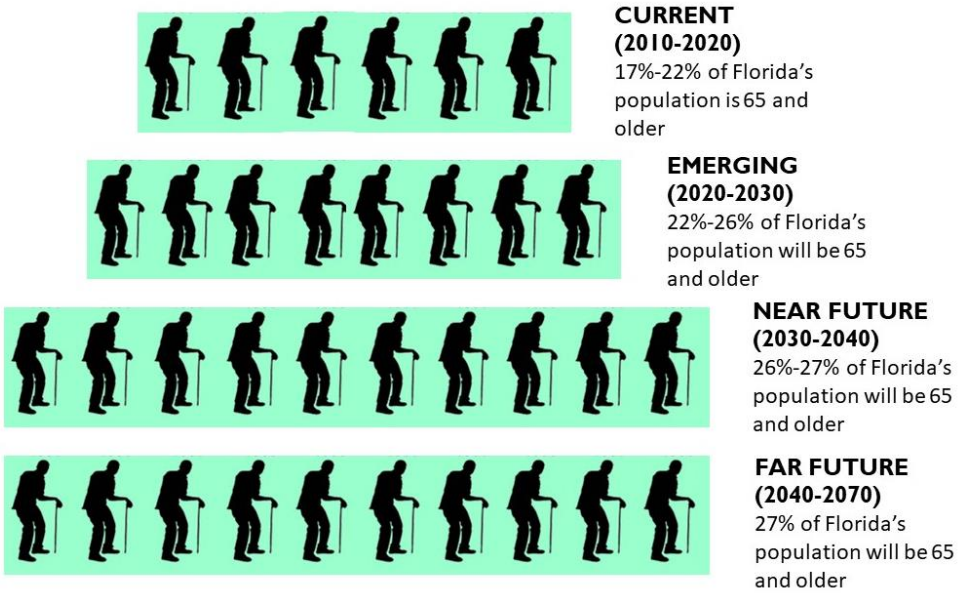


Figure 5. Florida's aging population

Source: Data obtained from Smith, 2015

Table 2 shows BEBR's "medium" projection series, or a moderate prediction of what the age structure of Florida might look like by 2050. Even a five percent increase in retirement-aged persons in Florida could spur substantial social, economic, and political changes, and may mirror the findings of other studies regarding the transportation behaviors of an older population – i.e. fewer non-auto trips, a preference for housing in new or established suburbs, and a reluctance to embrace e-commerce and other trip-replacing technologies (Smith, 2015).

Table 2. Florida Population by Age, 2010-2050, Medium Projection Series

Age	2010		2020		2030		2040		2050	
	Number	%	Number	%	Number	%	Number	%	Number	%
<15	3,284,608	17.5	3,493,251	16.5	3,884,584	16.3	4,129,409	15.9	4,405,682	15.8
15–44	7,177,939	38.2	7,651,976	36.1	8,327,208	35.0	8,818,210	34.0	9,440,904	33.8
45–64	5,079,161	27.0	5,444,585	25.7	5,465,198	23.0	6,104,572	23.5	6,649,186	23.8
65–84	2,825,477	15.0	3,949,135	18.6	5,173,744	21.8	5,538,602	21.3	5,615,613	20.1
85+	434,125	2.3	646,529	3.1	934,440	3.9	1,379,695	5.3	1,822,749	6.5
Total	18,801,310	100.0	21,185,476	100.0	23,785,174	100.0	25,970,488	100.0	27,934,134	100.0

Source: Smith, 2015

The majority (92%) of 65-69 year olds are retaining their driver's licenses in the 21st century, and many in this age range are continuing to work rather than retiring by age 65 (Zmud et al., 2014). As shown in Figure 6, the proportion of working people above 55 has increased more than any other age bracket since 1992, and is predicted to increase further in the coming years (BLS, 2013 as cited in Zmud et al., 2014). This affects travel behavior for this cohort, as vehicle miles traveled (VMT) tends to be higher during working years than during retirement (NHTSA, 2013).

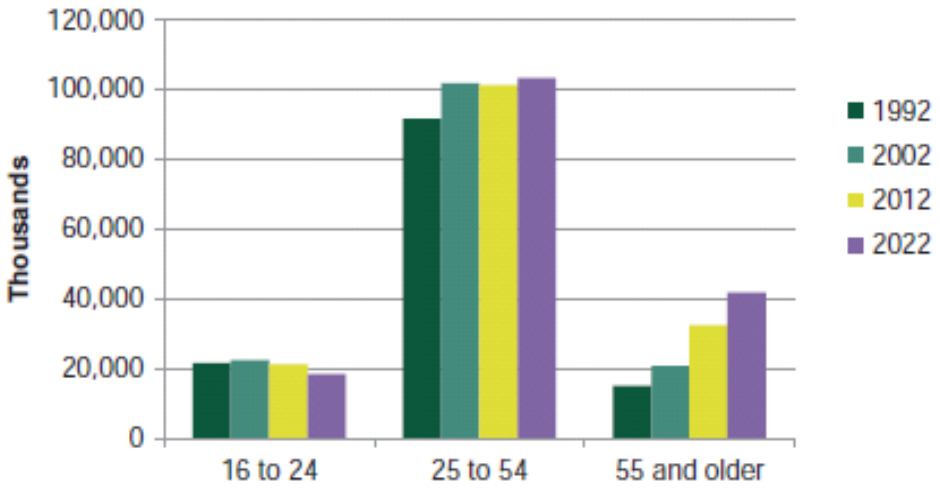


Figure 6. Civilian labor force by age

Source: BLS, 2013 as cited in Zmud et al., 2014.

As the population continues to age, more people will need affordable alternatives to driving. About 7.4 million Floridians are expected to be 65 or older by 2050. About 35% of older workers

ages 55-64 have no retirement savings, and many will face declining living standards or poverty in just 10 years (Ghilarducci et al., 2017).

Economy and Revenue

Erosion of User-Based Revenues

An important concern in transportation funding in the U.S. is a widening of the gap between transportation spending and user-based revenues. The erosion of user-based revenues is even more sobering when viewed in relation to vehicle miles of travel (Sorenson, 2013) (Figure 7). This analysis suggests a flattening of fuel tax revenue if left unadjusted for inflation: a more than 40% decline in real fuel tax revenue and a 60% decline in real fuel tax revenue per VMT. Sorenson (2013) notes that: "Together, federal and state fuel taxes currently provide around $70 billion in highway funding each year, accounting for about half of the nation's budget for road expenditures. A 40 percent decline in real revenue thus translates to tens of billions of dollars per year" (p. 13).

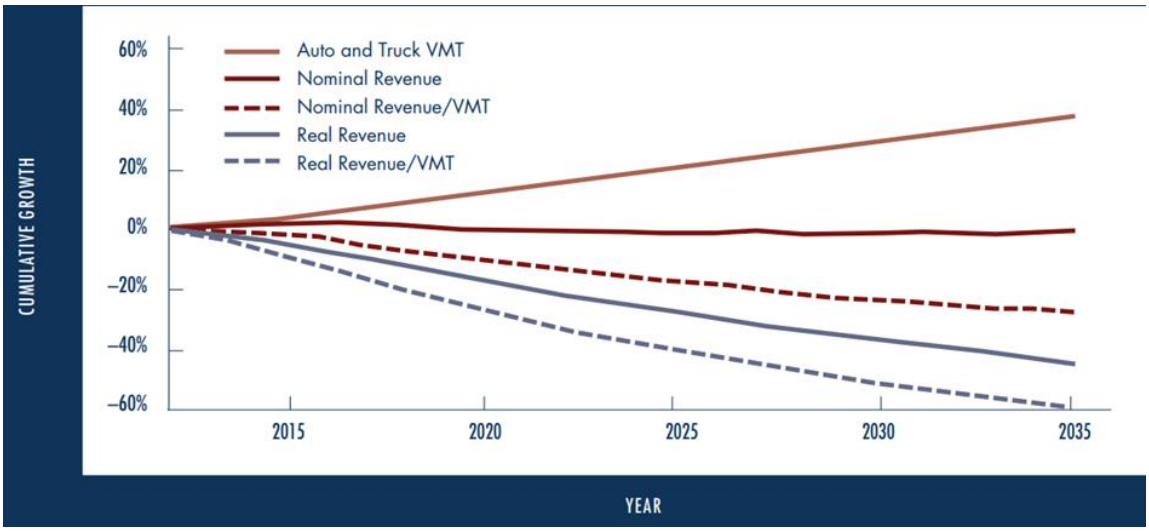


Figure 7. Potential erosion of federal fuel tax revenue.

Source: Sorenson, 2013

Causes include escalation of right-of-way and construction costs, fuel-efficient vehicles, and gas taxes that are not adjusted for inflation. Alternative user-based revenue streams are being explored, such as tolls, mileage-based fees, value capture, and congestion pricing. Current proposals for mileage-based user fees, for example, aim to collect revenue from all road users, including electric vehicles (EVs), bicycles, and transit, rather than strictly motor vehicle users. Many of the proposed revenue streams are regressive in their impacts on lower income people, raising equity concerns. In addition, government agencies are increasingly looking to the private sector to help fill the gap, leading to a growing private role in transportation, more complex business models, and pressure toward a "user pays" economy.

Growth in Freight and E-commerce

Freight transportation is an important part of the U.S. and Florida economy. Freight both contributes to economic growth and is driven by economic activity. Over 700 million tons of freight worth over $1.0 billion was moved in Florida in 2015 with 145 million tons inbound on the interstate, 530 million tons within the state, and 60 million outbound on the interstate (USDOT & BTS, 2017b). Projections by ARTBA (2015) show that truck freight is expected to continue to increase to $1.5 trillion by 2040 (Figure 8).

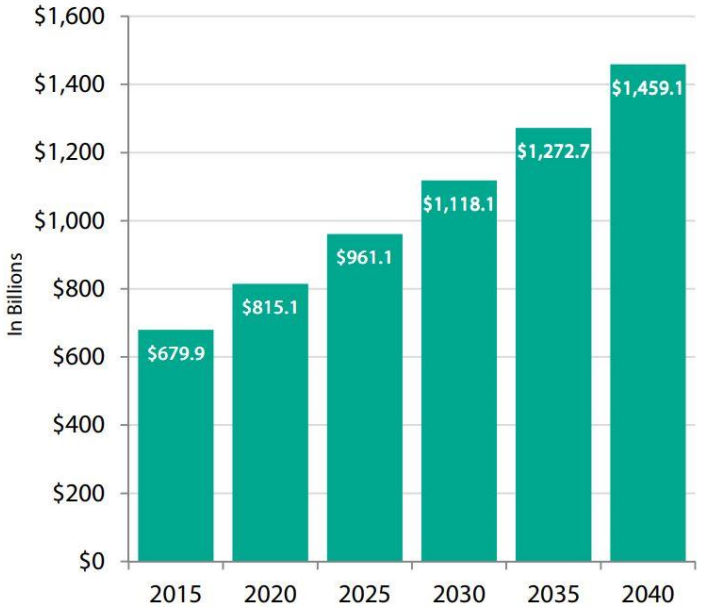


Figure 8. The value of Florida truck shipments.

Source: ARTBA, 2015

The global economy and demand for freight movement are leading to larger ships and trucks, and the recent explosion of e-commerce and same day delivery of goods is causing truck traffic to increase dramatically. Trends between 2013 and 2018 are already showing rapid increases in same-day delivery volumes (Figure 9).

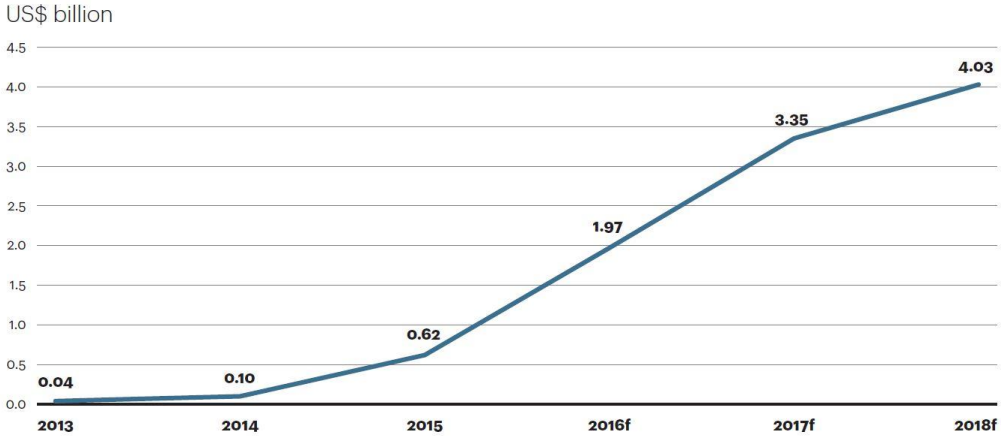


Figure 9. Same-day delivery market.

Source: Hu and Monahan, n.d.

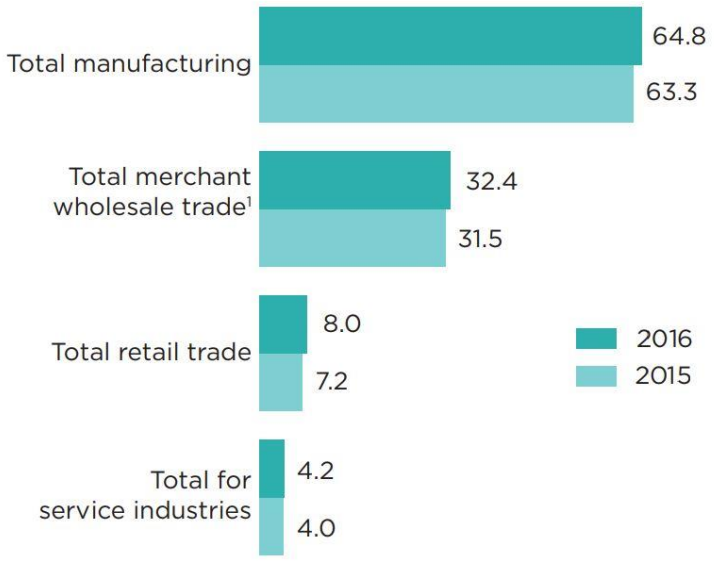


Figure 10. E-commerce as a percentage of total shipments, sales, and revenues: 2015-2016.

Source: U.S. Census Bureau, 2018

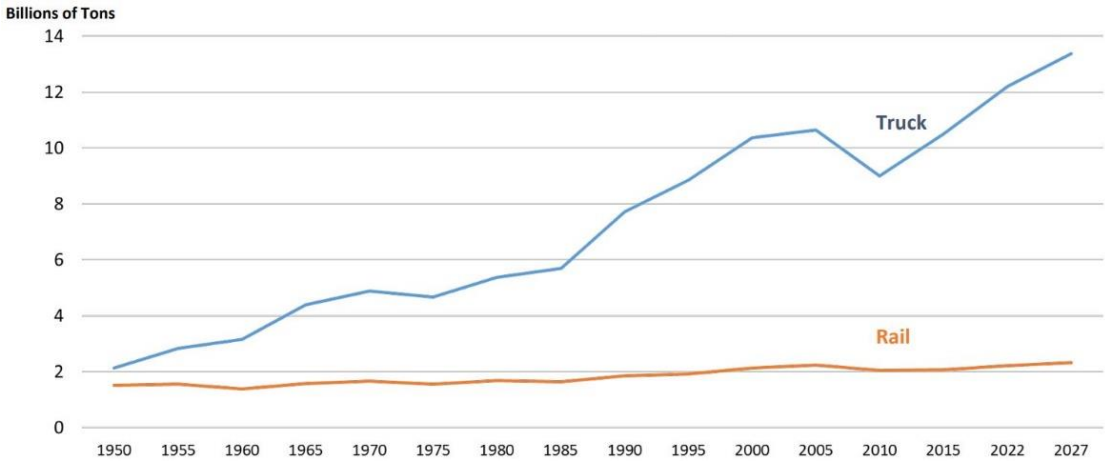


Figure 11. U.S. freight transportation forecast to 2027.

Source: EPA, 2017

Funding for freight-related projects in Florida consists of a combination of federal, state, local, and private funding sources (Figure 12) totaling $46,609 million for commitments in the 2017-2021 Five Year Work Program (FDOT, 2014). State funding for transportation projects in Florida originates from the State Transportation Trust Fund (STTF) (FDOT, 2014). The STTF as a primary funding source for freight projects has recently been identified as a significant risk for freight needs in Florida. Highway fuel taxes are one of the main funding sources for the STTF and recent trends, including vehicle fuel economy, threaten these revenue sources (FDOT, 2014)

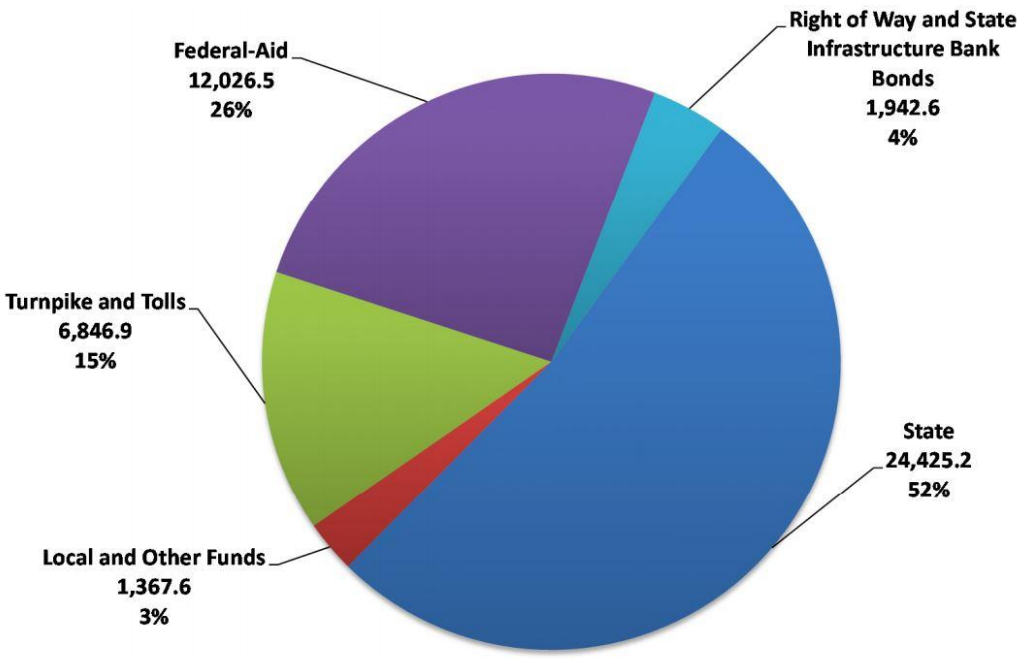


Figure 12. Funding sources for commitments FY 2017-2021 (in millions).

Source: FDOT Office of Comptroller, 2017

Automated and connected vehicles (AV/CV) and information and communications technology (ICT) could help with supply chain management, energy efficiency, and cost savings. Uncertainties include impact of freight growth on congestion and maintenance needs, how AV and other technologies could help, and shipment methods, especially for first/last mile deliveries (Figure 13). Deployment of AV/truck only lanes reducing delivery costs and improving safety, first/last mile delivery innovations (unmanned aerial vehicles, transportation network companies or TNCs) and crowdsourcing of warehouse capacity are among the freight-related changes that could ensue.

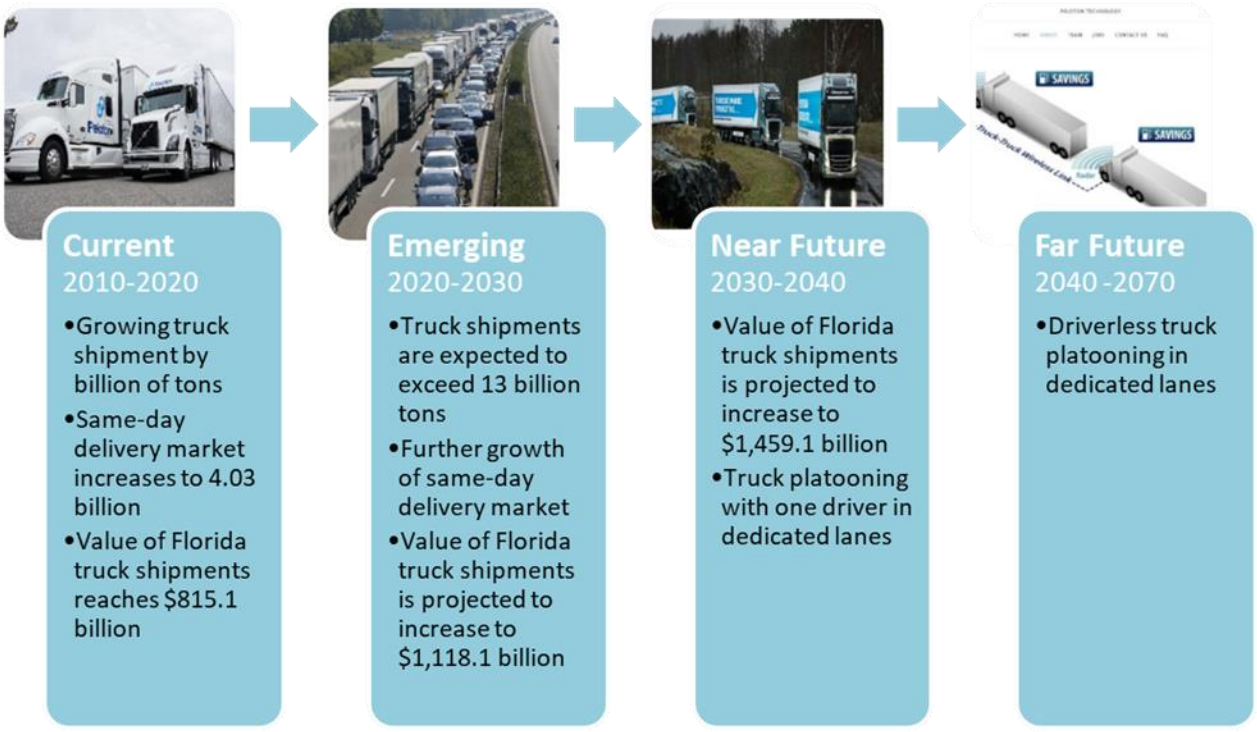


Figure 13. Growth in truck shipments in Florida and the advent of automation.

Advent of the Sharing Economy

Another driver of change and uncertainty for the economy is the advent of the sharing economy, defined as "an economic model often defined as a peer-to-peer (P2P) based activity of acquiring, providing or sharing access to goods and services that are facilitated by a community based on-line platform" (Investopedia, n.d.). The sharing economy is rapidly increasing with technological advances and yields a high level of uncertainty regarding tax revenue:

- The sharing economy is less regulated and taxed than other types of businesses causing a loss of tax revenue for local, state, and federal governments (Aslam & Shah, 2017; Miller, 2016).
- More or less tax revenue can be generated depending on how business transactions are structured. Although they do claim that many of these businesses classified under the sharing economy may design their transactions to pay the government less (Barry & Caron, 2017).
- Contrary to popular belief, the rules for taxation are adequate in regard to the sharing economy, but challenges do exist with tax compliance and enforcement due to ambiguity in tax laws and the improper filing of taxes (Oei & Ring, 2015).

Transportation in the sharing economy includes transportation network companies (TNCs) (car-sharing, ridesharing, ridesourcing, etc.). Car sharing in 2014 was less than 1% of the automobile market, but Saussier (2015) anticipates that "by 2020 there will be 26 million car-sharing

members globally (vs. 4 million in 2014) and 415,000 shared vehicles (vs. 75,000 in 2014)" (p.20). Impacts are identified as minimal but are expected to increase correspondingly with automation and scale. Schiller and Davis (2017) estimate that taxi and limousine companies, and independent drivers (including TNCs) brought in $17.5 billion in revenue in 2014 which would have contributed an estimated $1.2 billion in state and local sales tax revenue if collected. Edelman and Geradin (2015) identified a particular conundrum with the taxation of taxing transportation affiliated with the sharing economy:

> "First, transportation services appear to cause a negative externality through congestion. Each vehicle on the road slows the progress of others, and commercial vehicles are likely to distinctively frequent the congested city centers where this effect is largest. Congestion is a natural basis for taxation and an instance in which tax can, in principle, be particularly efficient as it both raises required government revenue and also reduces a negative externality. We note the limits to this argument. Taxing transportation platforms could reduce their operation and cause consumers to substitute downwards into mass transit, but these taxes could also cause consumers to retain private vehicles rather than switch to transportation platforms, probably increasing distance traveled and congestion" (p. 323-324).

Equity and Access to Opportunity

Transportation and the economy are interrelated in a myriad of ways. A good transportation system benefits the economy and enhances access to jobs, services, and opportunities. Transportation-disadvantaged populations often rely on public transportation to meet daily needs. Yet agencies are often pressured to reduce such service in periods of economic decline, even as demand for ridership increases. Conversely, transit ridership tends to decline as the economy improves or gas prices go down. Uncertainties surrounding this topic include the degree to which transportation investments support the economy, how transit investments influence ridership, and the cost of transportation. Studies suggest that:

- Transit investment can fail to increase ridership in less dense areas or during periods of economic growth.
- Transportation investments may or may not increase economic productivity and jobs.
- Lack of safe and affordable transportation options impedes access to opportunity.

Technology and Energy

Automated and Connected Vehicles (AV/CV)

The advent of automated and connected vehicles is among the more revolutionary changes in transportation. Figure 14 shows the possible timing of future changes associated with this technology, as obtained from various sources. Florida is a leader in advancing AV/CV laws and testing. Many uncertainties surround AV/CV, including the timing of deployment and adoption, infrastructure needs, liability and insurance, cybersecurity, and impacts on mobility, safety, system capacity, privacy, parking and land use.

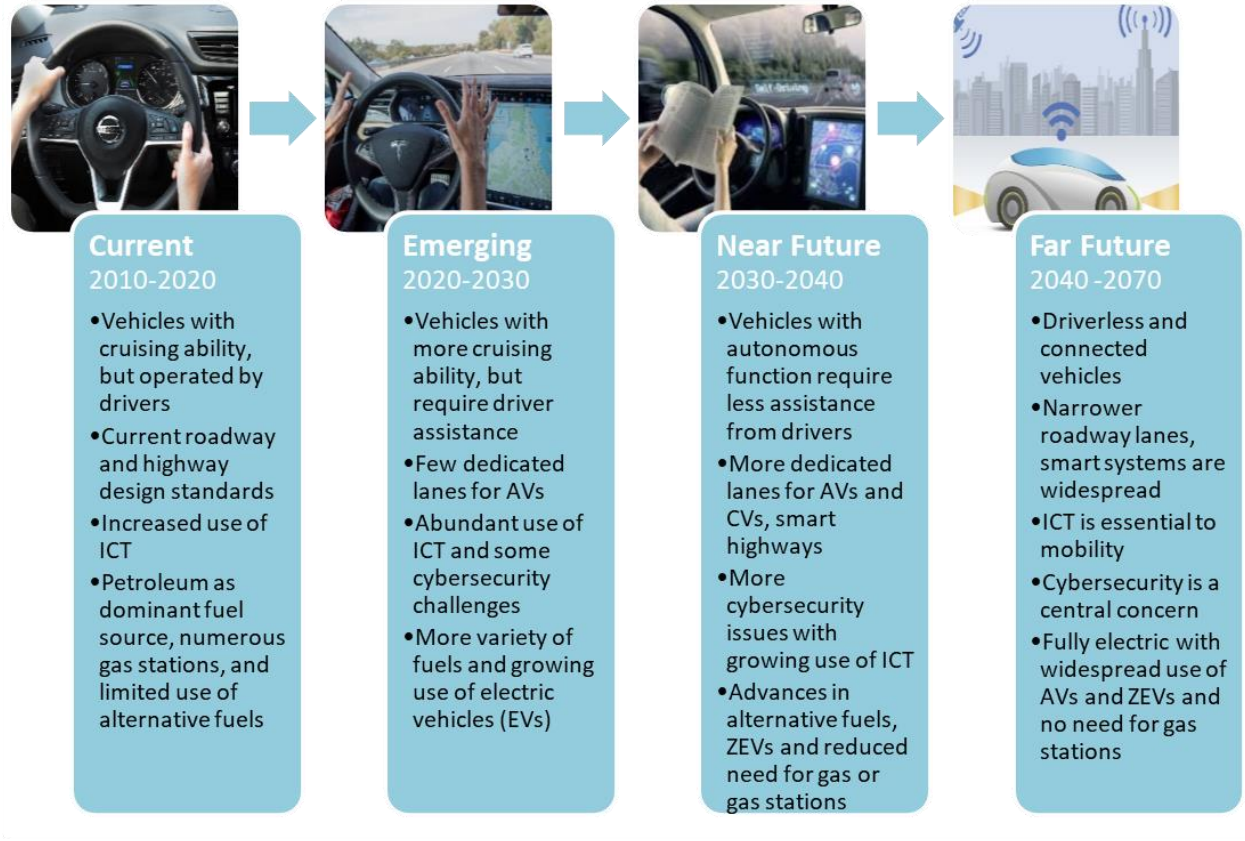


Figure 14. Possible evolution of vehicle automation, connection, and alternative fuels.

Predictions as to AV rollout vary depending upon when certain levels of automation will dominate the roadways. Most predictions suggest that AVs may not be commercially available until the 2030 or 2040s, given technical challenges and policy-related obstacles (Levinson et al., 2016; Shaheen et al., 2018). Figure 15 offers projections on AV market introduction levels based on optimistic and pessimistic sales, travel, and fleet factors. While Figure 16 illustrates U.S. vehicle fleet projections by level of automation.

As with AV rollout predictions, the timeline of CV market introduction is unclear. CV technology is currently being developed and piloted for vehicle safety applications. According to Zmud et al. (2017) numerous manufacturers are developing Dedicated Short-Range Communications (DSRC) devices and CV applications, as well as vehicle-to-everything (V2X) technology that uses cellular data, Wi-Fi, and Bluetooth capabilities. Implementation of these communication technologies and networks poses risks to safety and cybersecurity. Presently, Florida Statutes allow for the operation of AVs on roads within the state (FL State Statute 316.85) and additional laws allow for AV testing on public roads in Florida (Florida Department of Transportation, n.d.a).

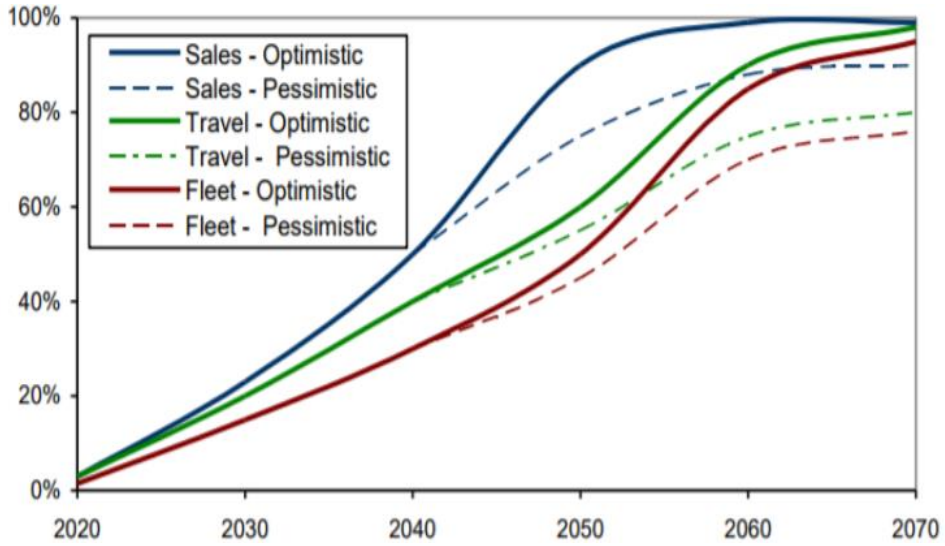


Figure 15. Optimistic and pessimistic AV sales, travel, and fleet penetration levels.

Source: Litman, 2017

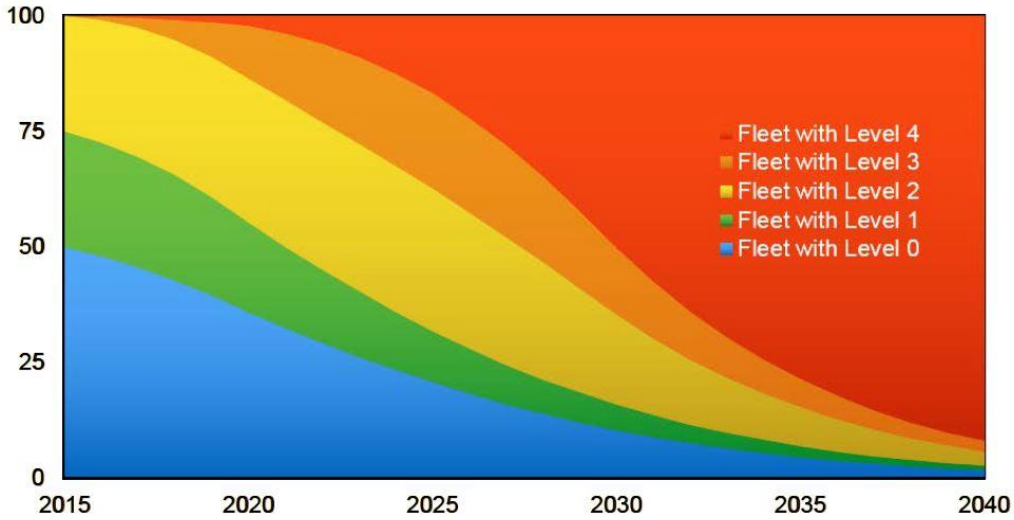


Figure 16. US vehicle fleet by NHTSA automation level.

Source: National Highway Traffic Safety Administration, n.d.

A key question relates to the infrastructure needed to serve AV/CV and whether states will be able to cover these costs. The role of the private sector will likely need to increase in this regard. Research suggests that once adopted, these technologies:

- Will reduce crashes, congestion, and air pollution.
- Could increase vehicle miles of travel and urban sprawl or reinforce mobility as a service and enable increased urban density.
- Could increase transit efficiency or reduce ridership.
- Provide an opportunity to repurpose right of way.
- Reduce the need for surface parking, but increase need for curb space and curb management.

Ridesourcing and Ridesharing

Advances in technology and abundant use of smart phones have enabled widespread use of ridesourcing (e.g., TNCs - Uber, Lyft) and ridesharing (e.g., carshare, bikeshare, shared TNC, etc.). The ability to share transportation resources through carsharing, bikesharing, and ridesharing services is leading to a "sharing economy." These services have the potential to reduce the number of vehicles on the road and transform personal mobility, particularly in urban areas. Economic and mobility benefits to Florida of Uber, for example, are shown in Table 3.

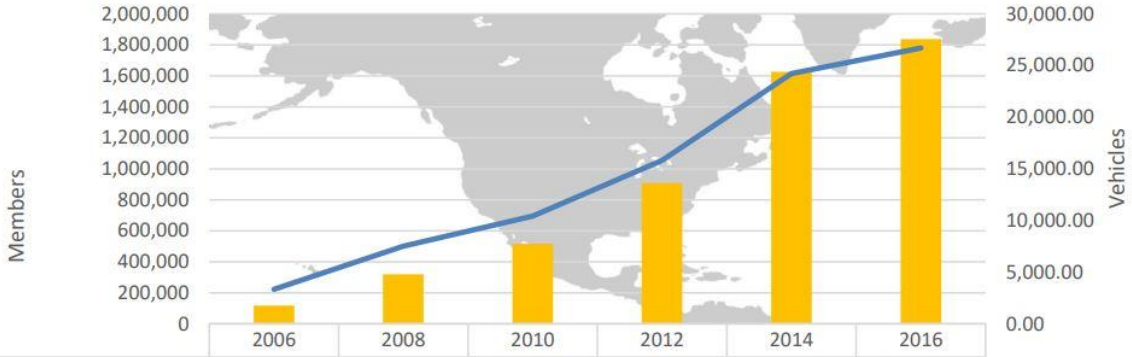
Table 3. Uber's Impact in Florida (2017)

State Economy	$6 million $134 million $1.1 billion	in tourism spending in net state impact[1] in gross state product[2]
Rider Benefits	$122 million $308 million $318 million $349 million	in monetary savings in time savings in parking cost savings in car ownership costs savings[3]
Driver Benefits	$469 million $873 million	in earned benefits in earnings
Mobility	6% 11.80% 17% 27%	of riders used Uber to complement their transit use of riders eliminated the need for a car (or second car) of riders used Uber to increase access[4] of visitors used Uber to travel to additional locations within the state

[1]$50 million contributed from increased business productivity and $78 million from increased local sales
[2]Strictly from ridesourcing operations, courier services not included in total gross state product
[3]For riders who chose Uber in lieu of personal motor vehicle ownership
[4]Increase access to places not connected by transit or were too far to walk to

Source: Economic Development Research Group, 2018

Ridesharing differs from ridesourcing. Ridesharing, such as carsharing and bikesharing, allow users to use vehicles or bikes in an on-demand fashion. National carsharing and bikesharing trends suggest a continued increase in their usage, as depicted in Figure 17 and Figure 18.



	2006	2008	2010	2012	2014	2016
Members	117,656	318,838	516,100	908,584	1,625,652	1,837,854
Compound Annual Member Growth Rate (2 yr)	0%	65%	27%	33%	34%	6%
Vehicles	3,337	7,505	10,420	15,795	24,210	26,691
Compound Annual Fleet Growth Rate (2 yr)	0%	50%	18%	23%	24%	5%
Member-Vehicle Ratio	35.3	42.5	49.5	57.5	67.1	68.9

Figure 17. North American carsharing trends.

Source: Shaheen et al., 2018

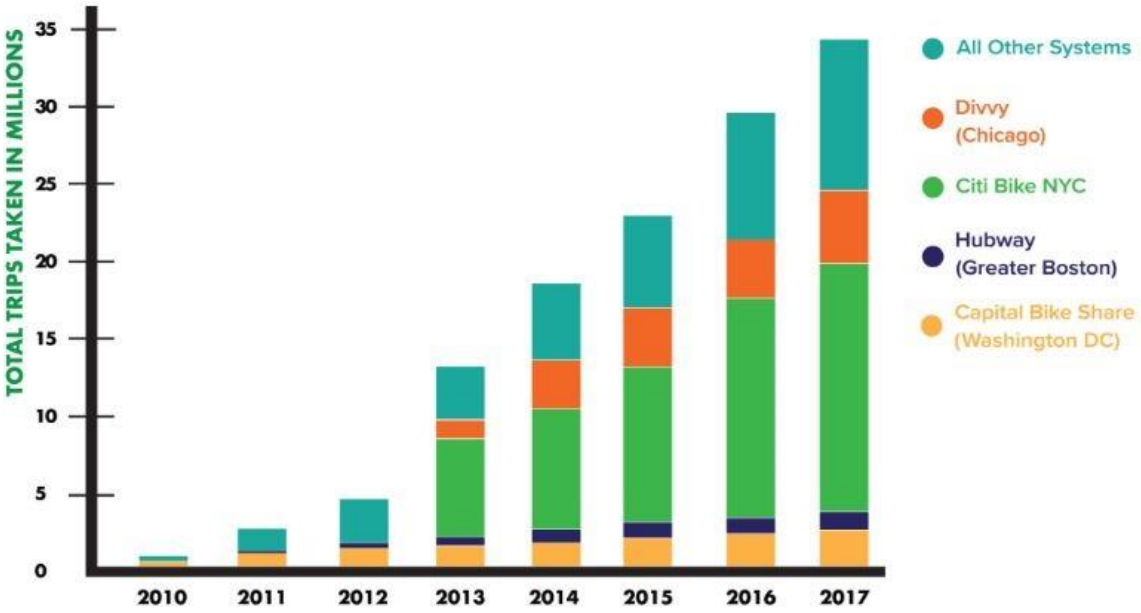


Figure 18. Growth in bikeshare ridership.

Source: National Association of City Transportation Officials, 2017

Uncertainties associated with ridesourcing and ridesharing include their rate of expansion, as well as impacts on car ownership, transit use, walking, cycling and congestion. These services could complement transit, but recent studies suggest that, more often than not, they compete with transit (as well as short walk and bike trips) and generate more car traffic. Nonetheless,

these services, together with the advent of AV/CV/ICT, promise to support multimodal integration and improved urban mobility. Future impacts, shown in Figure 19, could include:

- Growth and expansion of the sharing economy.
- May complement or compete with public transportation, walking and cycling.
- Potential to reduce car ownership or increase car trips and congestion.
- Growing need for curb space and curb space management.

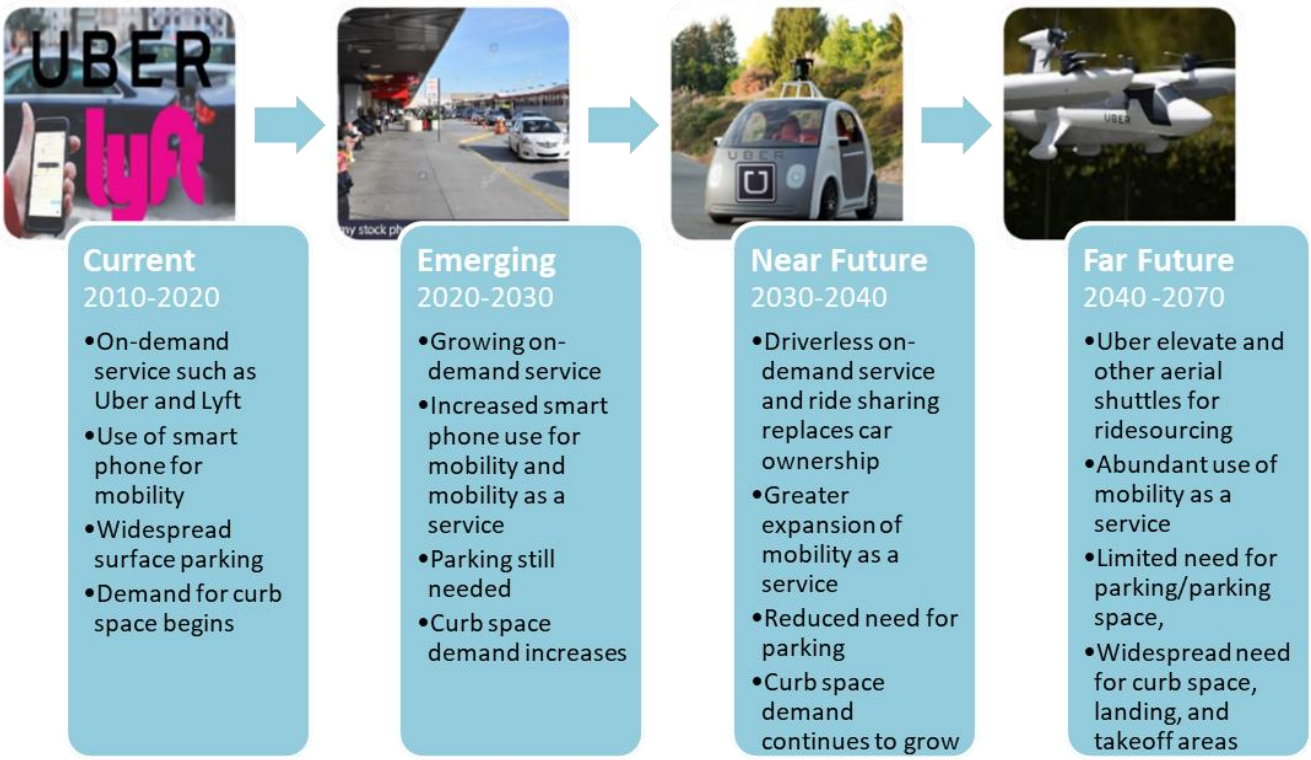


Figure 19. Possible evolution and impacts of ridesourcing and ridesharing services.

Alternative Fuels and Zero Emission Vehicles (ZEVs)

Use of electric vehicles (EVs) and charging infrastructure is increasing in the U.S. and Florida. In addition to an increase in personal EV ownership, the use of EVs in the transit industry is expected to grow even faster than for light duty vehicles. According to the U.S. Energy Information Administration, sales of ZEVs and EVs (electric vehicles) are projected to increase through 2050, (Figure 20).

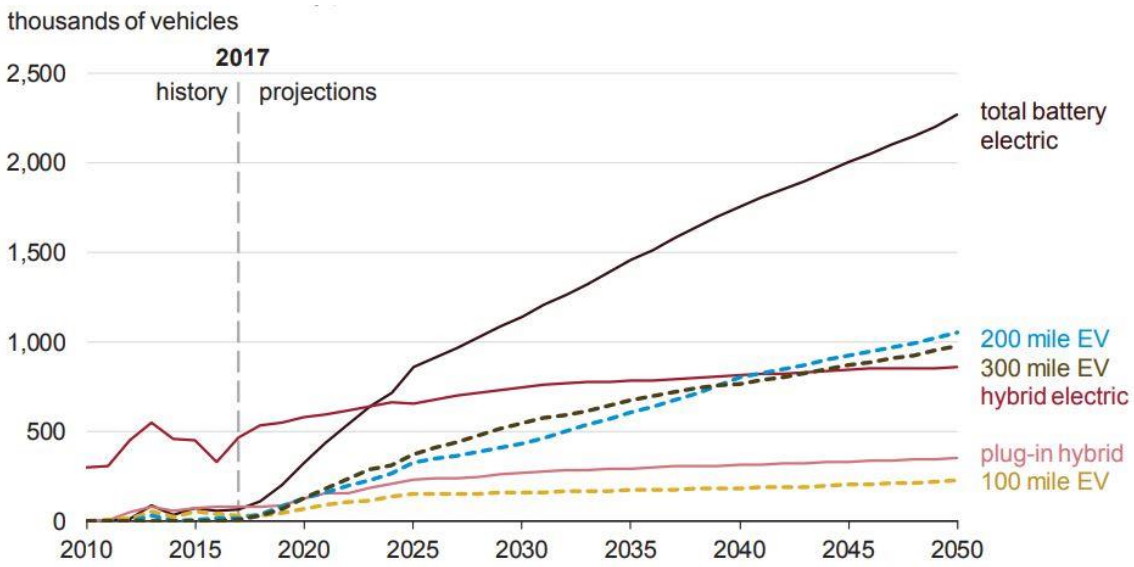
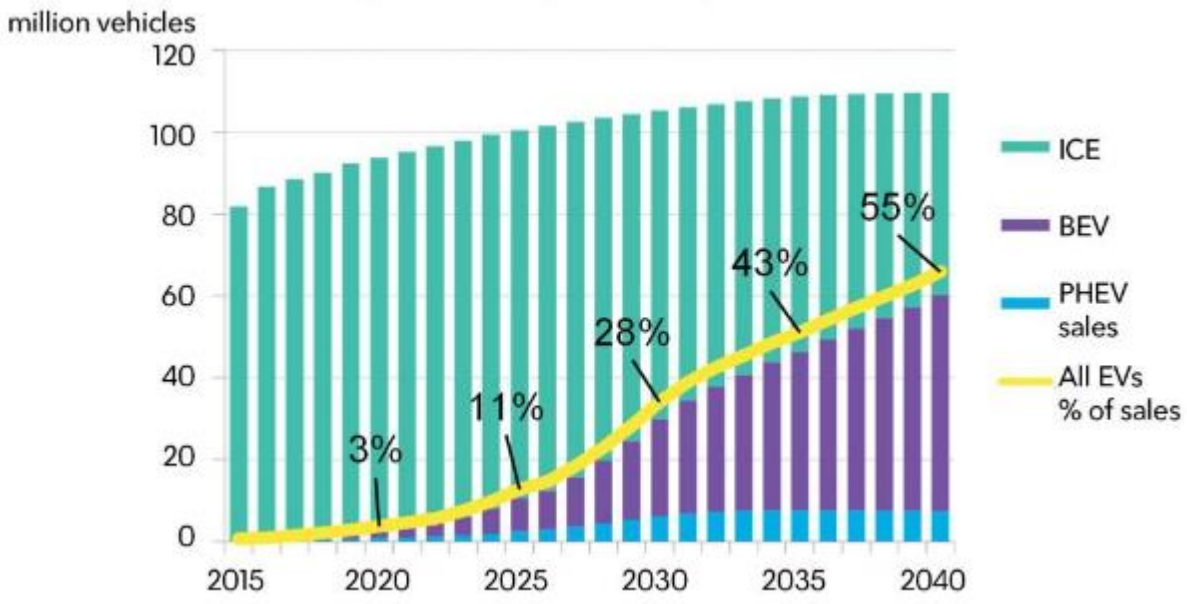


Figure 20. New vehicle sales of battery powered vehicles.

Source: U.S. Energy Information Administration, 2018

A key finding of a study by Shaheen et al. (2018) on the future of mobility offered two scenarios of electric vehicle (EV) adoption rates, "one scenario predicts that 95 percent of VMT will occur in shared, electric AVs by 2030. Another scenario predicts that 80 percent of shared AVs will be electric by 2040. Under a slow adoption scenario, if the rates of personal ownership stay constant, 37 percent of U.S. vehicles will by electric by 2042" (p. 33).

Plausible forecasts suggest that by 2040 most buses will operate on electricity (Bloomberg New Energy Finance, 2018). The 2018 electric vehicle study by BloombergNEF predicts that: "The electrification of road transport will move into top gear in the second half of the 2020s, thanks to tumbling battery costs and larger-scale manufacturing, with sales of electric cars racing to 28%, and those of electric buses to 84%, of their respective global markets by 2030." Figure 21shows the BloombergNEF (2018) forecasts.



ICE = internal combustion engine cars; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle

Figure 21. Annual global light duty electric vehicle sales.

Source: Bloomberg New Energy Finance, 2018

In addition, many diverse types of alternative fuels exist. Uncertainties include the potential of these fuels to replace or overtake petroleum, their impact on revenues, and availability of the appropriate infrastructure for their use. Alternative fuels such as natural gas, biofuels, electricity, and hydrogen have the potential to overtake petroleum as the dominant fuel source in the future. In addition to alternative fuels, a mix of fuel types may be prevalent in the future. Use of these alternative fuel sources offers reduced impacts to the environment in the form of GHG emissions and reduced energy costs related to travel (Sorensen, 2014). Figure 22 portrays the U.S. Energy Information Administration's 2018 alternative fuel consumption projections through 2050 for the transportation sector. Within the transportation sector, public transit has gradually incorporated the use of alternative fuels, specifically for improved bus operations. The use of these technologies in the future could lead to:

- Reduction in gas tax revenues.
- Reduced or no emissions.

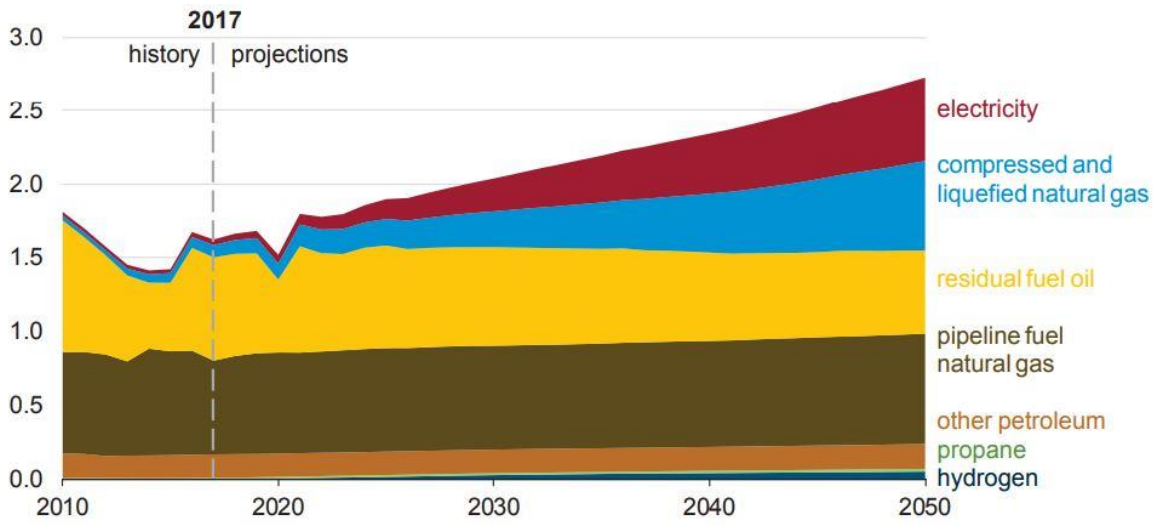


Figure 22. Transportation sector consumption of non-major petroleum and alternative fuels.

Source: U.S. Energy Information Administration, 2018

Other Technological Advances

Many other types of technology are emerging that can transform the future of transportation. Many questions surround how these different technologies will affect mobility, accessibility, safety, infrastructure, mode choice, and construction costs. Some examples are:

- 3-D printing, which could decrease production and construction costs.
- UAVs and flying shuttles that could be applied to freight delivery and regional air travel.
- Blockchain applications in transportation that could greatly strengthen digital security.

Hyperloop technology is being developed in the U.S. and some preliminary corridors have been identified, including a link between Orlando and Miami. If successfully implemented, Hyperloop technology would revolutionize long distance travel (see Figure 23) Many uncertainties surround the future of this technology, including the viability of the technology, impacts on long distance travel modes, cost, and impacts on the built environment. If the Hyperloop becomes available, it could:

- Dramatically shorten long distance travel times.
- Increase commuting distances.
- Result in greater economic productivity.
- Be self-powering and immune to weather disruption.

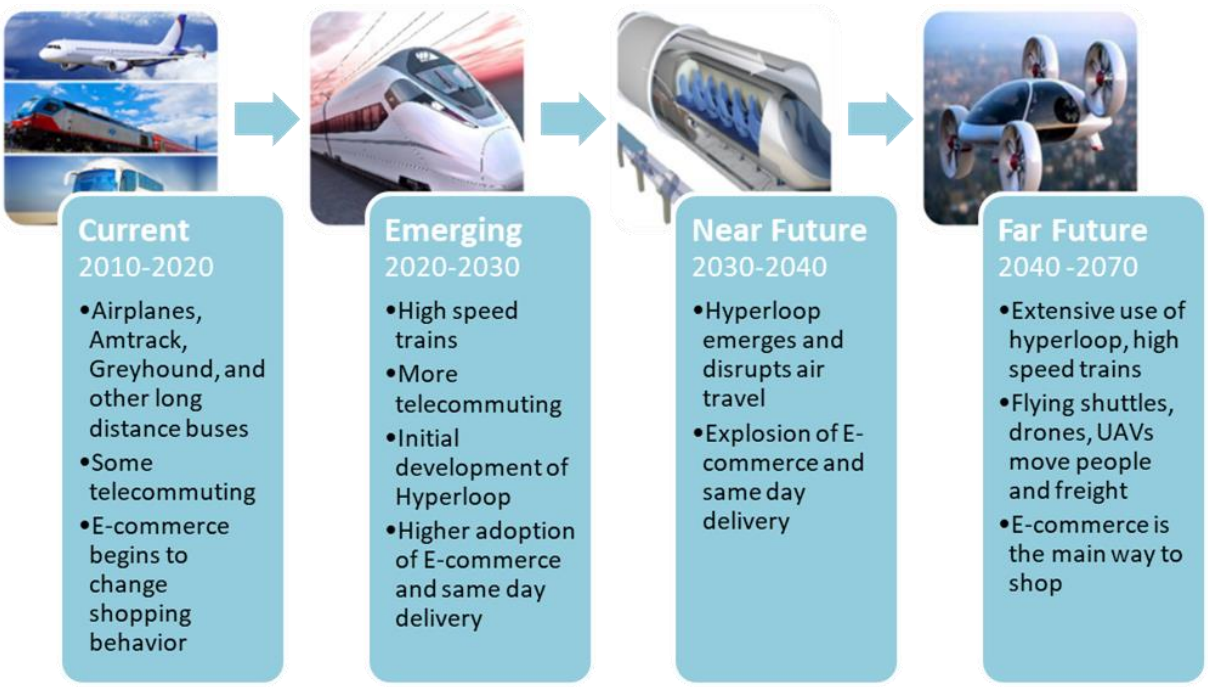


Figure 23. Long distance travel and freight transportation.

Environment and Natural Disasters

Natural Hazards and Climate

Changes in the climate have led to growth in natural hazards, such as wildfires, extreme heat, sea level rise, hurricanes, tornadoes, intense storms, and flooding. Global greenhouse gas (GHG) emissions have increased and global climate is changing, with future changes expected to happen even more rapidly than seen in historic trends (IPCC, 2014; Meyer et al., 2014; Melillo et al., 2014). Meyer et al. (2014) and Melillo et al. (2014), have drawn the following conclusions:

- Temperatures have increased by approximately 1.9°F since record keeping began in 1895 and is projected to increase by about 4°F by 2050 relative to 2010 (Figure 24).
- The number of days below freezing will decrease in many areas, particularly southern locations.
- Average U.S. precipitation has increased by almost 5% since 1900 and is projected to continue to increase (Figure 25).
- The intensity, frequency, and duration of hurricanes have increased since the early 1980s. Recent research has suggested that there could be fewer hurricanes, but the ones that do occur will be even stronger.
- Global sea levels have risen since reliable record keeping began in 1880 and is projected to rise up to 6 feet by 2100.

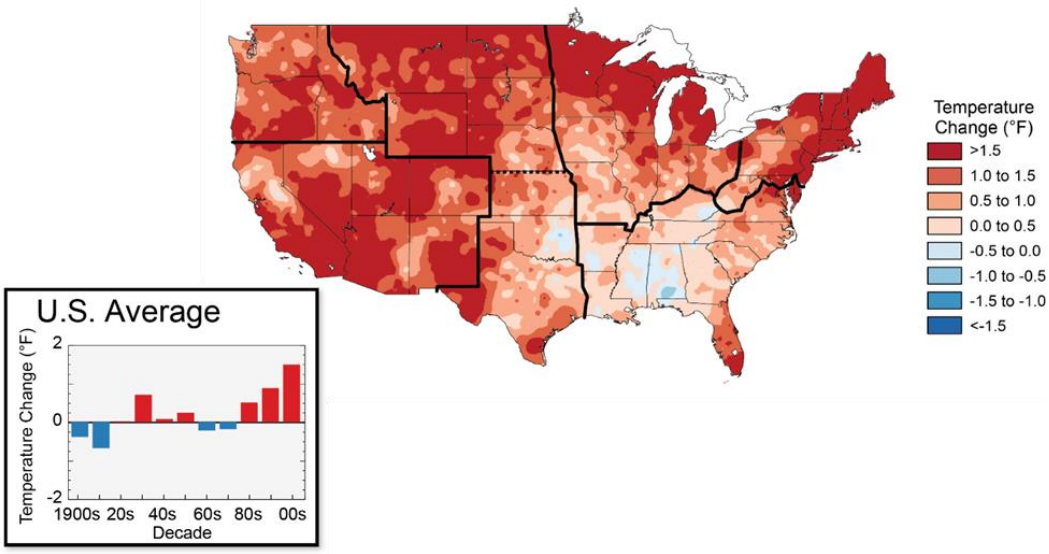


Figure 24. Observed U.S. temperature change.

Source: Melillo, Richmond, and Yohe, 2014

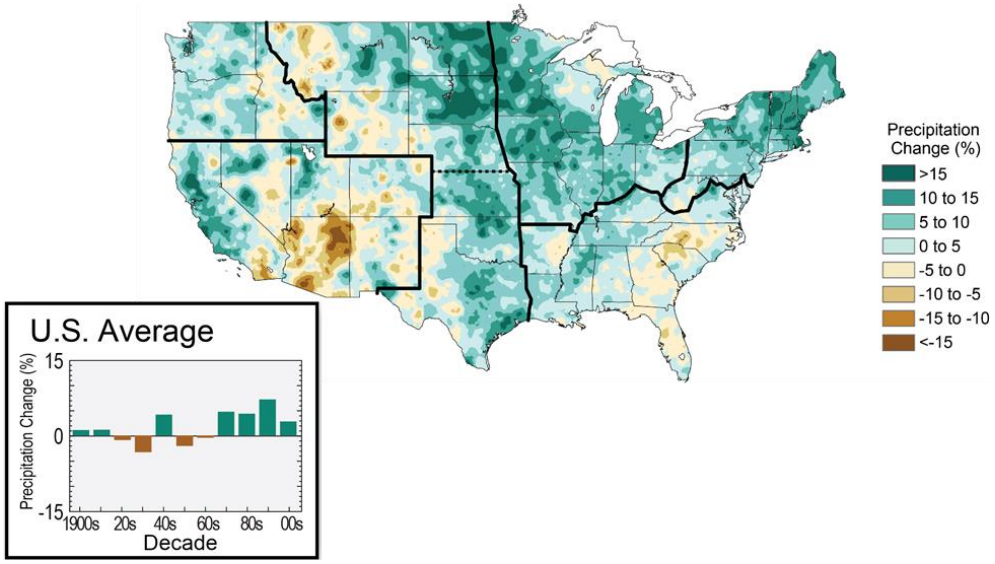


Figure 25. Observed U.S. precipitation change.

Source: Melillo, Richmond, and Yohe, 2014

Climate change exacerbates environmental or "climate stressors" due to temperature extremes, radical instabilities in precipitation, and extreme weather events that cause wildfires, droughts, floods, sea level rise, landslides, geologic subsidence, rock falls, snow, ice, earthquakes, storms, hurricanes, and tornados that increase the vulnerability of valuable societal assets (Meyer et al., 2014; U.S. Department of Transportation, n.d.; TRB, 2008; Melillo et al., 2014). The Southeast U.S. is especially vulnerable to sea level rise (Figure 26), extreme heat (Figure 27), and hurricanes, experiencing more billion-dollar weather/climate disasters between 1980 and 2012 than any other region (Melillo et al., 2014).

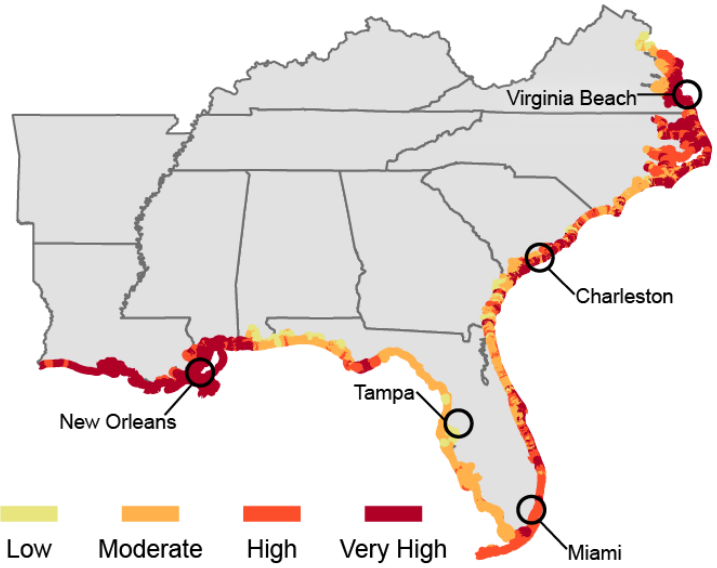


Figure 26. Southeast vulnerability to sea level rise.

Source: Melillo, Richmond, and Yohe, 2014

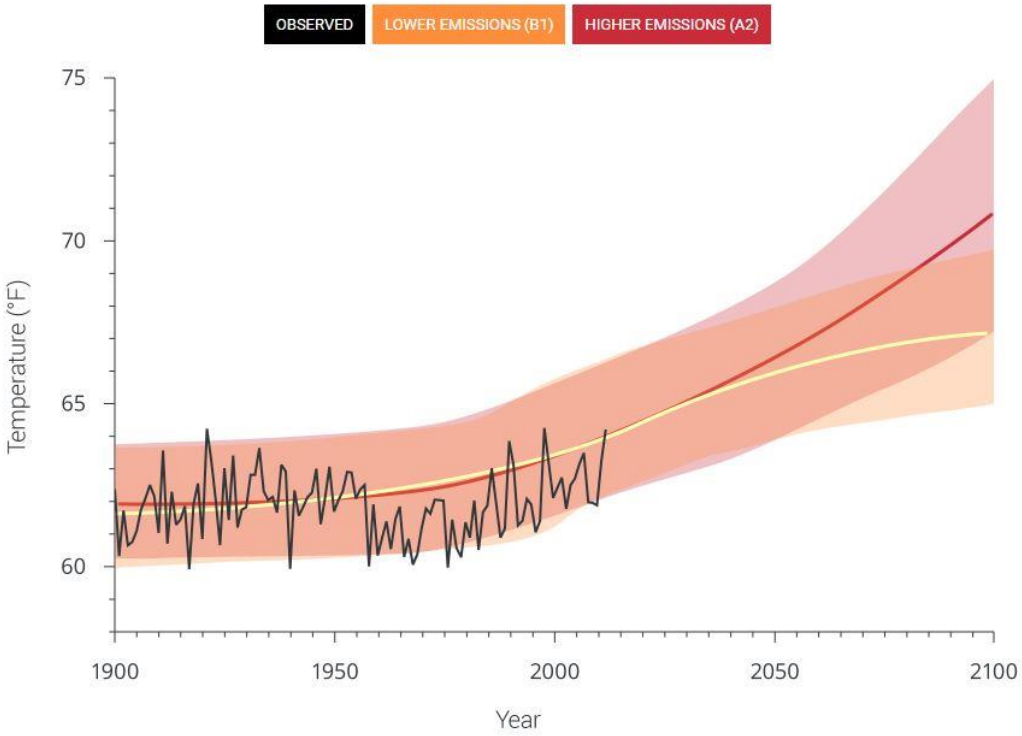


Figure 27. Southeast temperature: observed and projected.

Source: Melillo, Richmond, and Yohe, 2014

Uncertainties related to this topic include: When and by how much will the sea level rise in Florida? What actions can we take to reduce greenhouse gas emissions from the transportation

sector? Which locations will be affected and to what extent? To what degree might these unfortunate events disrupt the economy? How could we mitigate the impacts on coastal areas? What assets will be at greatest risk? The gradual increase in temperature, sea level, precipitation, and hurricane's intensity as a result of climate change is illustrated in Figure 28. Impacts of natural hazards and climate change include:

- Road and rail closures.
- Airline delays and cancellations.
- Weather related crashes and traffic disruptions.
- Impediments to evacuation routes.
- Limited construction activities.
- Economic disruption and decline.

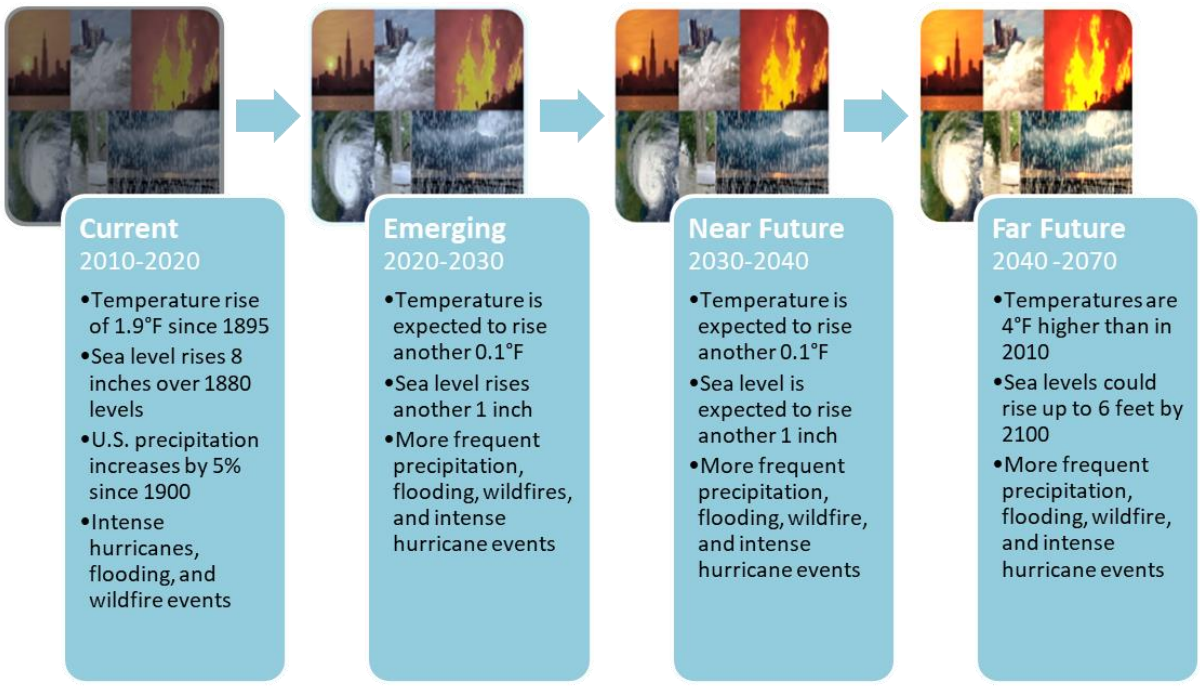


Figure 28. Natural hazards and climate change timeline.

Source: Data from Melillo et al., 2014

Long-Term Issues for Florida

In an analysis of transportation funding in Florida, the Metropolitan Planning Organization Advisory Council summarizes several long-term issues facing the state (MPOAC, 2011):

- Revenue uncertainties.
- Environmental/community livability/growth management.
- Transportation, international trade, and economy.
- Security, emergencies, and safety of the transportation system.
- New capacity.

These issues, described in Table 4, contribute to the drivers of change and uncertainty identified earlier in this chapter.

Table 4. Long-Term Issues Facing Florida

Issues	Description

Long-term revenue uncertainties	• Insufficient funding for long-term transportation needs
	• Potential uncertainties can significantly impact revenue collection:
	  ○ A growing market for more fuel-efficient cars (hybrids, compressed natural gas, electric, gasohol, etc.)
	  ○ Significant price increases for fuel
	  ○ National emphasis on alternative fuels and technologies
	  ○ Telecommuting
	  ○ An aging population and the reality that the elderly drive less than younger drivers so they consume less fuel

Environmental/community livability/growth management issues	• Inadequate consideration of community livability coupled with sprawl and long commuting patterns adding strain to the transportation system
Transportation, international trade, and Florida's economy	• Investments in the transportation system are linked to job creation, retention, and the economy
Security, emergencies, and safety of the transportation system	• Increased attention to the security of transportation facilities • Recently mandated security measures impacts efficiency of movement and funds • Vulnerability to hurricanes and natural disasters need to be considered for their impacts on the transportation system and to ensure effective emergency response
New capacity	• Population, visitors, and economic activity is projected to grow increasing risk to Florida's ability to provide for the mobility of people and freight • Investment in transportation has not kept pace with growth due to limited resources, increasing construction and right-of-way costs, and constraints (physical and policy) on adding capacity to many transportation facilities

Source: MPOAC, 2011

Chapter 3
Evaluating and Managing Consequences of Risk and Uncertainty

This chapter explores concepts and methods for evaluating and managing the potential consequences or "risk events" attributable to uncertainties or drivers of change. It begins by defining key concepts in the evaluation of risk, including likelihood, consequence/impact, level of vulnerability, and overall risk. Next, methods used to identify and categorize risks are examined, as well as strategies to manage consequences. Assets at risk (existing or planned) are considered, as are opportunities that may emerge. The chapter concludes with a summary of key methods and tools in risk management from the literature.

Key Concepts and Definitions in Evaluating Risk

Likelihood

Likelihood can be defined as, "the estimated potential occurrence of an event" (Proctor, Varma, Roorda, 2016, p.223), or in much simpler terms, "the chance of something happening" (Curtis et al., 2012, p.11). Likelihood or probability can be developed "by extrapolating from past occurrences, expert judgment, or estimates of likelihood" (Proctor et al., 2016, p.15). In the example given in Table 5, likelihood ranges from almost certain to exceptionally rare. The frequency is determined by how often an event occurs in a given time period (annual, biennial, etc.). Likelihood is reported by percentage and a value from 1 (exceptionally rare) to 5 (almost certain) is assigned to each level.

Table 5. Overall Likelihood Scale.

Likelihood Table			
Level	Frequency	Likelihood	Value
Almost certain	Occurs almost annually	95 percent	5
Probable	Occurs approximately once every two years	50 percent	4
Possible	Occurs approximately once every five years	20 percent	3
Rare	Less than once every 10 years	Less than 10 percent	2
Exceptionally rare	Occurs once every 100 years	1 percent or less	1

Source: Proctor et al., 2016

According to Curtis et al., (2012, p.20) a likelihood assessment "concerns the likelihood of a key risk event occurring over a given period." An example of a likelihood scale for a 5-year period is provided in Table 6.

Table 6. Likelihood Scale over a Five-Year Period.

Level	Descriptor	Likelihood Over 5 Years
1	Rare	>0.02% (less than 1 in 5,000 chance)
2	Unlikely	0.02% to <2% (1 in 5,000 to 1 in 50 chance)
3	Possible	2% to <20% (1 in 50 to 1 in 5 chance)
4	Likely	20% to <75% (1 in 5 to 1 in 2 chance)
5	Almost Certain	>75% (more than 7 in 10 chance)

Source: Curtis, Dailey, D'Angelo, DeWitt, Graf, Hankel, & Rocco, 2012

Consequences and Impacts

The U.S. Department of Homeland Security (DHS) defines consequence as the "effect of an event, incident, or occurrence" (2010). DHS further explores various types of consequence, including direct consequence, which is an "effect that is an immediate result of an event, incident, or occurrence," and indirect consequence, which is an "effect that is not a direct consequence of an event, incident, or occurrence, but is caused by a direct consequence, subsequent cascading effects, and/or related decisions."

Curtis et al. (2012) defines consequence as the "outcome of an event affecting objectives" (p.11), states that an impact assessment "concerns the impact of a key risk event" (p.21), and identifies the following ways that impact can be considered:

- Time – When is the risk likely to occur?
- Cost – Consideration of the cost of the risk occurring against the cost of preventing its occurrence.
- Delivery – How badly would this risk disrupt what we are trying to deliver?
- Reputation – How much damage would this event do to the reputation of the agency?

Table 7 shows an example of how impacts can be ranked, including a description of the magnitude of impact at each level.

Table 7. Impact Assessment

Level	Impact	Description
1	Insignificant	Almost no impact
2	Minor	A noticeable impact, but not a significant one
3	Moderate	Now the impact is noticeable and has a material effect on the relevant area
4	Major	The impact threatens to seriously damage the affected area
5	Catastrophic	The impact is almost all-encompassing

Source: Curtis, Dailey, D'Angelo, DeWitt, Graf, Hankel, & Rocco, 2012

Throughout the literature, consequence and impact are used interchangeably. For the purpose of this report, "consequence" will be used.

Level of Vulnerability

Berdica (2002, p.119) defines vulnerability in the transportation system as "a susceptibility to incidents that can result in considerable reductions in road network serviceability. These incidents may be more or less predictable, caused voluntarily or involuntarily, by man or nature." Three classifications of vulnerability include:

- Vulnerability may be understood as the fragility of an asset (potential for asset failure or reduced asset functionality) (Meyer et al., 2014), or the likelihood that the event actually results in the estimated consequences (Machado-Leon & Goodchild, 2017).
- Asset vulnerability is the susceptibility of a specific asset to a given threat of a specified magnitude (Herrera et al., 2017).
- Network vulnerability deals with network weakness and the consequences of failure (Herrera et al., 2017).

Three approaches to assessing vulnerability are identified by FHWA (2017a):

- Stakeholder input – relies on institutional knowledge to identify and rate potential vulnerabilities.
- Indicator-based desk review – relies on available data to score and rank transportation assets for vulnerability.
- Engineering informed assessments – relies on asset specific data and analysis which helps agencies anticipate the effectiveness of specific adaptation measures and return on investment.

Similarly, Taylor (2017) identifies four (4) approaches to assessing vulnerability:

- Inventory-based – considers transportation network components and assets which can be affected by degradation.
- Topologically based – analyzes a network in terms of its basic structure and connectivity and identifies critical locations in the network based on centrality and contributions to network connectivity.
- Serviceability-based – considers the transportation network and its component (node and link) attributes in detail and examines the operational performance of the network in different states of degradation and travel-demand loads.
- Accessibility-based – considers the transportation network in detail with a focus on the broader impacts of network degradation in terms of the impacts on social and economic systems in the region served by the network.

Overall Risk

Risk is typically associated with negative outcomes for life, health, economic, or environmental conditions (Taylor, 2017). In this context, it is defined as the probability that a potentially

negative incident or event will occur, and the extent and severity of the resulting consequences, should the incident or event occur) as seen in Figure 29 (Berdica, 2002; Taylor, 2017.

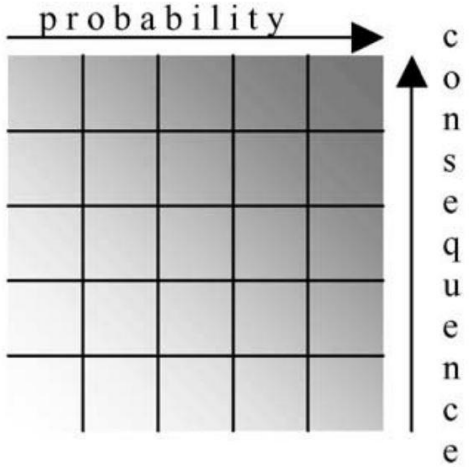


Figure 29. Risk Matrix

Source: Berdica, 2002

In contrast, FHWA (2012a) identifies several sources that define risk as more than a threat or hazard, but *also as an opportunity*. Proctor et al. (2016, p.3) define risk as "the positive or negative effects of uncertainty or variability on agency objectives." These opportunities are classified as risks because they impact objectives, and there is a level of uncertainty (positive or negative) associated with the possible outcomes. FHWA (2012a, p.5) therefore defines risk as "the positive or negative effects of uncertainty or variability upon agency objectives" and identifies risk analysis as an evaluation of "the probability of risk with its consequence."

Another more detailed variation of the risk matrix, seen in Figure 29, is the risk scale or risk register, seen in Table 8 and Table 9. Table 8 considers likelihood and consequence, identifying a risk scale of low, moderate, significant, and high. Table 9 measures the likelihood and impact of each risk, identifying the likelihood of an event by percentage within a 36-month period using a scale of low, moderate, high, and extreme. More information on risk registers is included under the *Risk Management Tools* section of this chapter.

Table 8. IIMM Risk Scale

LIKELIHOOD	CONSEQUENCE				
	1	2	3	4	5
A	L	L	L	M	S
B	L	L	M	S	H
C	L	M	S	H	H
D	M	M	S	H	H
E	M	S	H	H	H
F	S	H	H	H	H
SCALE: Low, Moderate, Significant, High					

Source: FHWA, 2012a

Table 9. TransLink Agency Risk Scale

Likelihood (36 months)		Likelihood	Risk Map			
≥ 90%	Almost Certain	5	M	H	E	E
≥ 70% to > 90%	Likely	4	M	M	H	E
≥ 25% to < 70%	Possible	3	L	M	M	H
> 1% to > 25%	Unlikely	2	L	L	M	H
≤ 1%	Rare	1	L	L	L	M
Impact		Impact	1	2	3	4
			Minor	Moderate	Major	Extreme

Source: FHWA, 2012a

Given these definitions of risk, in addition to the sources identified by Aven & Renn (2009), risk can be divided into two categories where risk is expressed: (1) by means of probabilities and expected values, and (2) through events/consequences and uncertainties.

Risk, according to Machado-León & Goodchild (2017, p.46) is the product of "the potential consequences of a hazard-asset pair (C); the vulnerability (V), or the likelihood that the event actually results in the estimated consequences; and the likelihood of the threat (T)." Herrera et al. (2017) and Machado-León & Goodchild (2012) express risk as:

Risk = Consequence x Vulnerability x Threat

Identifying and Categorizing Transportation Assets

Risk analysis should include an evaluation of transportation asset vulnerability to the consequences of identified risks. Insight into the type of transportation assets that may be

impacted can be obtained through a review of inventories, including Transportation Asset Management Plans (TAMP) (FHWA, 2013), and vulnerability assessments (VDOT et al., 2012). For these studies, assets typically include roads, railways, and bridges, but support facilities, vehicles, ITS, and ecosystem-related assets can also be considered (FHWA, 2017a). Vulnerability assessments not only include asset identification, but also asset prioritization based on asset vulnerability (VDOT et al., 2012).

A vulnerability assessment completed by the Virginia Department of Transportation (VDOT), categorized assets as mobile and immobile to include railways, pavement, roads, bridges, tunnels, and traffic management center facilities (VDOT et al., 2012). VDOT et al., (2012, p.8) considers four major criteria for identifying critical assets and defines them as: "(1) those assets that are on hurricane evacuation routes…; (2) those assets that carry high traffic volumes…; (3) those assets that represent a maintenance priority route; and (4) those assets that are at low-lying elevations." In addition, FHWA (2017b, p.13) advises that agencies may "want to identify high-risk, high-value assets. These assets could be critical high-cost, high-traffic facilities, or even low-volume facilities, if they are the only facility serving a large area."

The Ohio Department of Transportation (Ohio DOT, 2011) groups assets into highway, structure, safety, multimodal assets and real estate. Table 10 shows the specific categorization of Ohio DOT's assets.

Table 10. Example Categories of Critical Transportation Assets

HIGHWAY ASSETS	STRUCTURE ASSETS
Pavement Interchanges (including ramps) and intersections Livability and environmental items, i.e., adopt-a-highway; gateway communities; endangered species; wetlands; vegetation (no mowing zones); etc.	Bridges Culverts Mechanically Stabilized Earth (MSE) retaining walls Ditches Catch basins Under/edge drains
SAFETY ASSETS	**MULTIMODAL ASSETS**
Barriers, i.e. Guard rails Signals Signs Lighting Systems, i.e. fixtures; poles; controllers; etc. Pavement markings, i.e., raised pavement markers (RPMs); stripping; rumble strips and stripes; sidewalks; ADA assets; etc.	Railways and Yards Ports Bikeways Airport runways and Heliports Intermodal Facilities
REAL ESTATE ASSETS	
Excess land (vacant parcels) Right-of-way	

Source: Ohio DOT, 2011

The Oregon Department of Transportation (Oregon DOT) considers assets to include state highways, airports, and railroads. Specifically, Oregon DOT identifies assets to include pavements, bridges, bike lanes, sidewalks, vehicle fleet, freight/intermodal, environment, and traffic control systems (Meyer, 2007). Further, Oregon DOT divides assets into linear and nonlinear assets. Linear asset priorities include culverts, tide gates, right-of-way, traffic barriers, pavements, bridges, retaining walls. Nonlinear asset priorities include computer software, data, equipment, and vehicles; facilities; special management areas and archaeological areas, as well as Transportation Management Operation Centers (Meyer, 2007, p.2-77).

Overall, numerous types of transportation assets may be found in any given state or region. Identifying the assets at risk may involve prioritizing based on specific criteria or agency goals. Some of the agency measures, values, goals, or levels of service that could be undermined by the assets at risk could include (Ohio DOT, 2011; GDOT, n.d.):

- Safety
- Performance
- Reliability
- Resiliency
- Cost
- Funding and Economic

Identifying and Categorizing Risks

Before level of risk can be assessed, the risks or risk events should be identified. Several techniques can be used to identify risks, including (Proctor et al., 2016):

- Brainstorming – a facilitated discussion (structured or informal) to collect diverse ideas.
- Interviews – open ended questions to obtain feedback.
- Delphi technique – a list of questions with a numeric scale is developed allowing for a quantification of responses. Averages, the distribution of responses, and other patterns can be analyzed.
- Checklists – a list of likely risks developed from past experiences and used as triggers to determine if the risk is likely. This technique does not identify new risks.
- Step-by-step process reviews – a review of the steps, inputs, and partners needed to complete an objective. Discussing each step may trigger identification of risks.
- Scenario analysis – considers how risks could occur under different scenarios and is useful for identifying risks under different scenarios.
- Cause and effect – a discussion where the group states each risk in a complete sentence with a subject, verb, and objective to full articulate risks. Aides in analyzing the effects of the risk and identifying the root causes.
- Categorize risks – identify risks based on categories to prompt the recognition of risks or opportunities.

Graphical mapping can be used to document the risks identified. Proctor et al. (2016) categorized risk into four (4) categories (Figure 30):

- Strategic risks – could affect the entire department and help or hinder the achievement of its major priorities.
- Program risks – could affect performance of our major programs, including safety, pavements, bridge, maintenance, information technology, local programs, project delivery, finance, and human resources.
- Project risks – could affect the cost, scope, schedule, quality, and impact of construction projects.
- Activity risks – could affect major ongoing activities, such as snow and ice control, incident response, maintenance of traffic control devices, communication network operations, equipment maintenance, and data collection.

Figure 30. Example of graphical mapping of risks.

Source: Proctor et al., 2016

In the example provided by FHWA (2012b), risks are categorized as financial, strategic, operational, or hazard (Figure 31). The events in the inner circle of Figure 31 are identified as having the highest likelihood and greatest possible impacts. Additionally, synergies and compounding risks should be identified during the risk identification process.

Figure 31. Example of graphical mapping of risks.

Source: FHWA, 2012b

The information identified through graphical mapping is then put into a risk register and ranked by likelihood, consequence, overall rating (likelihood X consequence), and color-coded as a heat map (Table 11). It is a comprehensive list of risks and how they are being addressed as part of the holistic risk management process (Curtis et al., 2012, p.14). A description of risk registers as a risk management tool is provided later in this chapter.

Table 11. Example of Risk Register

Risk Event	Liklihood	Consequence	Rating
Inadequate information systems **Risk Mitigation Strategy/Treatment:** Invest in updated information systems	0.90	0.70	0.63
Budget Shortfalls **Risk Mitigation Strategy/Treatment:** Monitor budget, prepare contingency program strategies	0.70	0.80	0.56
Inadequate asset inventories **Risk Mitigation Strategy/Treatment:** Invest in updated asset inventories	0.70	0.70	0.49
Maintenance failures **Risk Mitigation Strategy/Treatment:** Increase training, audit maintenance processes	0.70	0.70	0.49
Price increases **Risk Mitigation Strategy/Treatment:** Monitor bid prices monthly and prepare contingencies	0.30	0.70	0.21
Loss of experienced asset management staff **Risk Mitigation Strategy/Treatment:** Institute succession planning, training, mentoring	0.30	0.70	0.21
Changing legislation **Risk Mitigation Strategy/Treatment:** Monitor legislation. Inform legislators of impacts	0.30	0.30	0.09
Economic downturn **Risk Mitigation Strategy/Treatment:** Monitor economic activity and plan contingencies	0.30	0.30	0.09
Public opinion **Risk Mitigation Strategy/Treatment:** Sustain robust public information processes	0.30	0.30	0.09
Environmental standards **Risk Mitigation Strategy/Treatment:** Train staff to comply with standards. Conduct audits.	0.30	0.30	0.09
Lack of management support **Risk Mitigation Strategy/Treatment:** Train mid-level staff. Ensure compliance with TAM.	0.10	0.70	0.07
Barge strikes to bridges **Risk Mitigation Strategy/Treatment:** Install navigational warnings.	0.10	0.70	0.07
Excess vehicular loadings **Risk Mitigation Strategy/Treatment:** Monitor truck weights on vulnerable routes. Urge enforcement.	0.10	0.70	0.07
Rising interest rates **Risk Mitigation Strategy/Treatment:** Monitor interest rates. Time bond issues accordingly.	0.10	0.30	0.03
Flood **Risk Mitigation Strategy/Treatment:** Install storm event gauges. Countermeasures at scour-prone structures.	0.10	0.30	0.03
Seismic events **Risk Mitigation Strategy/Treatment:** Develop contingency planning for detours, emergency repairs.	0.01	0.70	0.01

Risk Likelihood	L	Impact	I
Almost certain	0.9	Extreme	0.9
Highly likely	0.7	Very high	0.7
Likely	0.3	Medium	0.3
Unlikely	0.1	Low	0.1
Rare	0.01	Negligible	0.01

Source: FHWA, 2012b

To conduct a risk assessment, Perseus (n.d.) suggests having some level of quantitative and qualitative information available, and an understanding of the consequences to ensure that the different levels of impact are properly structured. Consequences should be worded so that they are not directly associated with uncertainty, but such that they have a formal likelihood associated with them. The time period for the risk (consequence and likelihood) should be specified, and the likelihood score should directly relate to the consequence level occurring (not just the likelihood of the event occurring).

Strategies to Manage Consequences

Once risk events (positive or negative) have been identified, actions can be taken to address those threats or opportunities. According to WSDOT (2014) and El-Karim et al. (2015), threats can be:

- Avoided – action is taken to ensure the probability or impact of a threat is eliminated. This action can include removing the cause of the risk, or executing the project differently to achieve project objectives.
- Transferred – action is taken to allocate ownership for more effective management of a threat. This action does not eliminate the threat, it instead finds another party who will take responsibility for managing the threat and take on the liability should it occur.
- Mitigated – action is taken to reduce the probability and/or impact of the threat to an acceptable threshold.

Alternatively, opportunities can be:

- Exploited – action is taken to ensure the benefit of an opportunity is realized, ensuring a positive impact.
- Shared – action is taken to share the opportunity with a third party who is able to maximize the potential benefits.
- Enhance – action is taken to increase the probability of an opportunity by strengthening the cause of, or reinforcing the conditions that result in an opportunity, trigger conditions are proactively targeted and reinforced.

Finally, threats or opportunities can be accepted. Acceptance is when no action is taken and the risk remains, because response actions are seen as not cost effective, or because the risks are uncontrollable. According to El-Karim et al. (2015), acceptance of threats should also include a contingency plan. Similarly, Proctor et al. (2016) and FHWA (2012b) identified five (5) options for risk management, called the 5Ts:

- Tolerate – it is determined that the risk is low, the chance of occurrence is unlikely, or the risk is outside of agency control. In these cases the agency simply monitors activity.
- Treat – the agency acts on and mitigates the risk.
- Transfer – the risk is transferred to another entity.
- Terminate – the risk is terminated by stopping a practice or eliminating the source of the risk.
- Take advantage – this tactic usually occurs after an agency has evaluated a risk and found the potential opportunities exceed the likelihood of negative consequences.

Risk Management Methods

This section draws from the literature in the field of risk management to offer strategies for managing risks faced by state transportation agencies and their potential consequences. Due to

the cyclical and repetitive nature of the risk management process, planning for risk needs to be flexible and seamlessly adaptable, as new information regarding risk and uncertainty is acquired. The methods that follow are examples that accommodate adaptability and incorporate risk management throughout the various stages of planning and levels of risk management.

Adaptive Planning

Adaptive planning embodies resilience and flexibility. It addresses and mitigates uncertainty and risk by assessing the feasibility and effectiveness of planning decisions *throughout* the planning process and project implementation (Kato & Ahren, 2008). In doing so, adaptive planning and policymaking shifts the planning process from a "predict" and "provide" approach to a "decide" and "provide" approach – one that consciously seeks to shape the future. It involves continual monitoring and evaluation to allow for new knowledge to be gained that is then used to update the plan or project to more effectively address uncertainty, manage risk, and achieve societal goals.

Throughout the adaptive planning process, the feasibility and effectiveness of planning decisions and risks are monitored and evaluated through the use of a feedback loop (Figure 32). As a result, adaptive planning reduces vulnerability to uncertainty and risk, while increasing the ability to harness opportunities that lead society toward a desired future. This approach to planning acknowledges the limitations of the rational planning method, which relies on the "world as we know it", by embracing flexibility and resilience rather than a predetermined "end state".

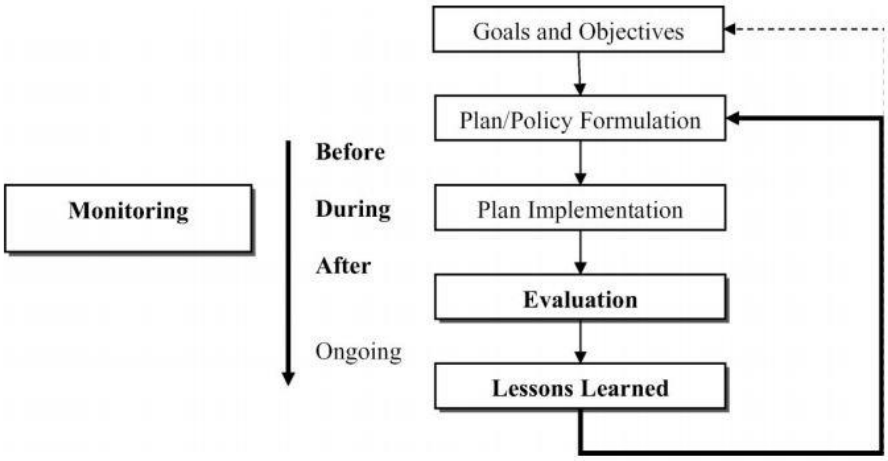


Figure 32. Adaptive planning method

Source: Kato & Ahren, 2008

Kwakkel et al. (2010) developed a framework for adaptive airport strategic planning. Their goal was to make airport planning more robust by considering multiple uncertainties and multiple plausible futures and producing a plan that is flexible and robust across different futures. The framework was built using the following three approaches from the literature:

1) **Dynamic strategic planning** provides a flexible plan making approach. To address multiple plausible futures, the first stage is well defined, but multiple options for subsequent stages are developed.
2) **Adaptive policymaking** (also discussed in the following section) provides the ability to modify or change plans and policies as new knowledge is acquired.
3) **Flexible strategic planning** builds on the dynamic strategic planning approach, but encourages "pro-active planning".

The basic steps in the framework include stage setting, assembling basic policy, increasing the robustness of the basic policy, contingency planning, and the implementation phase (Figure 33). Like the ADM process, this framework can be applied to a broader range of planning processes.

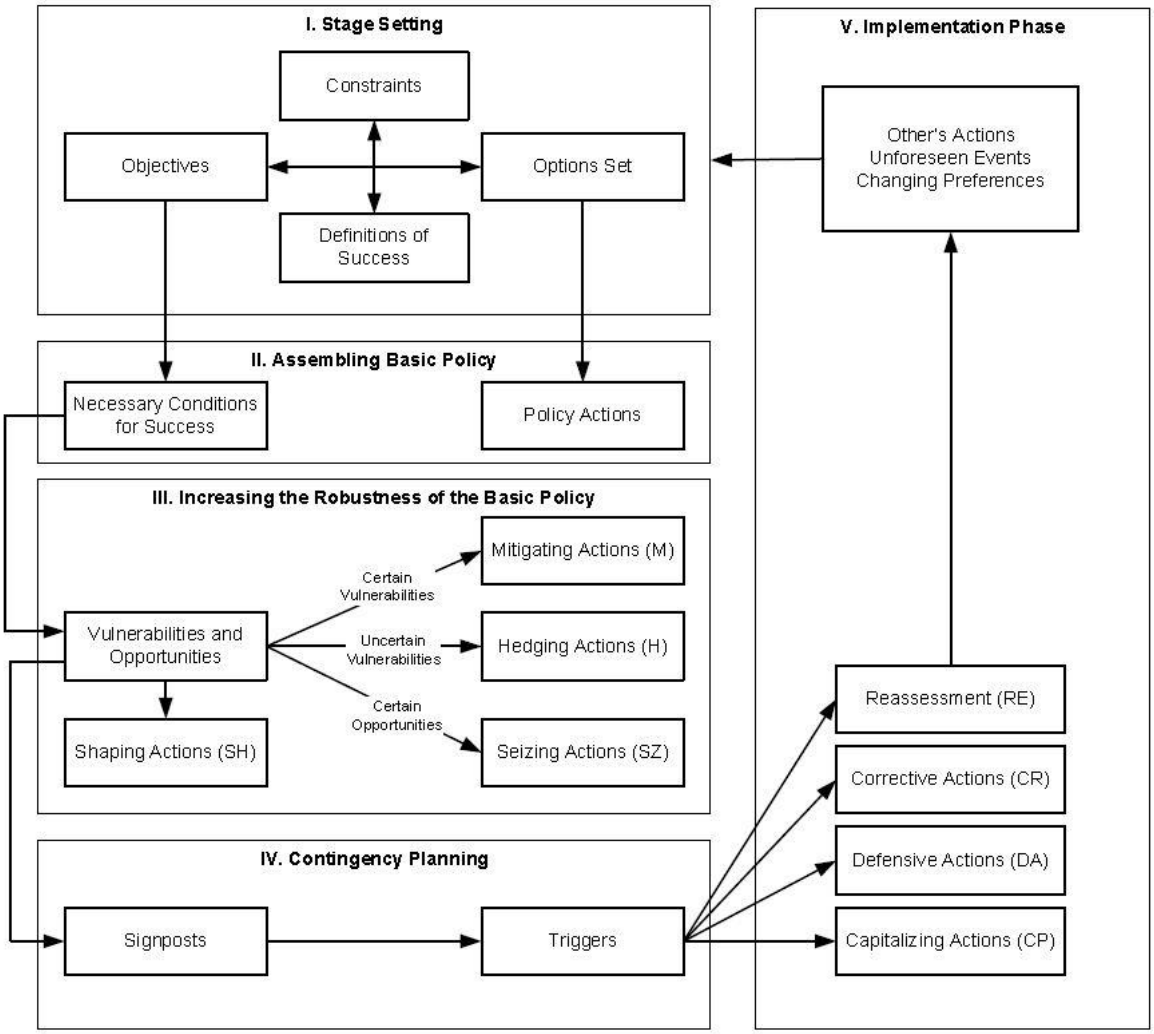


Figure 33. The steps of adaptive airport strategic planning

Source: Kwakkel et al., 2010

Adaptive Policymaking

Adaptive policymaking is a means of creating more dynamic and adaptive plans. It embodies a dynamic approach to policymaking that protects against, and plans for, known and unforeseeable uncertainties (Walker et al., 2010). Adaptive policies or strategies embody provisions that are responsive to change and allow adaptation based on new knowledge gained over time related to uncertainty and risk through a monitoring process. These policy measures address potential impacts of uncertainty before they take place, rather than reacting to impacts when they occur. The end goal remains the same; although policy actions that are implemented over time may change, they continue in the direction of achieving policy goals. Should the end goal change, then a new plan, guided by new policy, must be developed (Marchau et al., 2010).

Adaptive policies reduce the risk of wrongly investing in future policies and plans by introducing flexible and proactive characteristics into the planning process. Flexibility in the planning process is derived from policy decisions that are based on the awareness of changing conditions and the fact that action is required to return to, maintain, or achieve a desired state (Walker et al., 2010).

Adaptive policymaking has the capability to adapt to anticipated uncertainties, or "known unknowns", as well as to unanticipated uncertainties, "unknown unknowns". To do so, policymaking must incorporate the following characteristics (Swanson et al., 2010):

- Integrated and forward-looking analysis;
- Built-in policy adjustment;
- Formal policy review and continuous learning;
- Multi-stakeholder deliberation;
- Enabling self-organization and social networking;
- Decentralization of decision-making; and
- Promotion of variation.

Rather than a policy designed to be optimal for a "best estimate" future, an adaptive policy would be robust across a range of possible futures and make explicit provision for learning (Marchau et al., 2010). This process is illustrated in Figure 34.

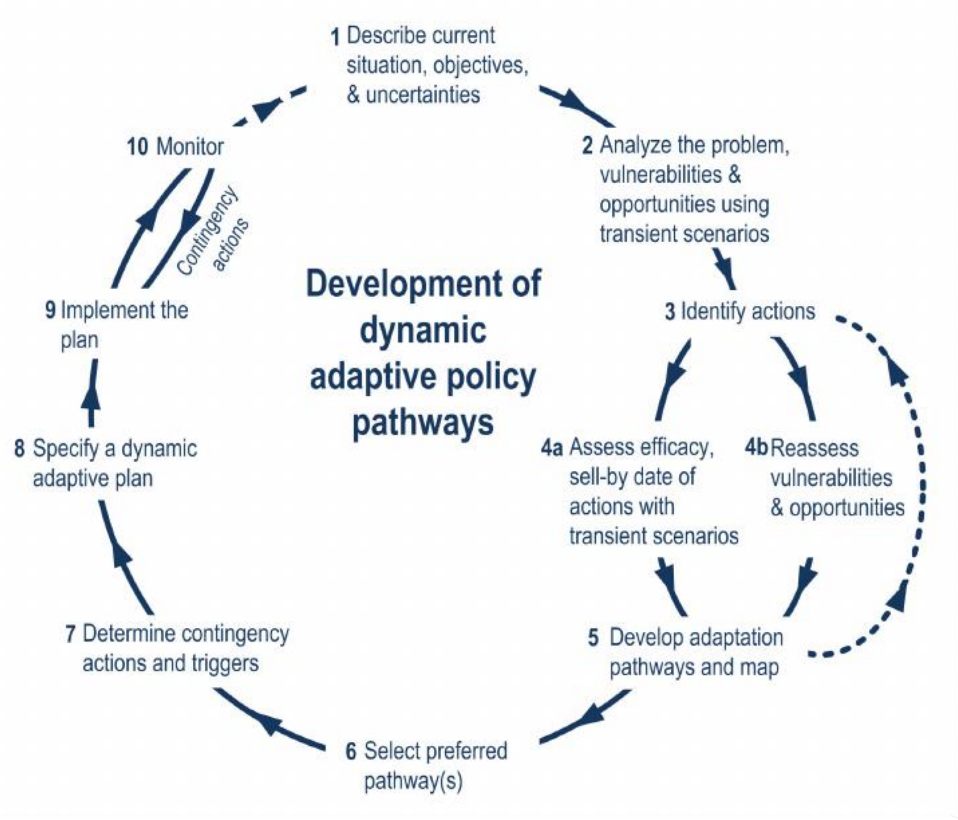


Figure 34. Dynamic adaptive policy pathways approach

Source: Haasnoot et al. 2013

Examples of adaptive policy strategies are those that fit one or more of the following criteria (Quay, 2018):

- Strategies already being done for some other purpose (main stream);
- Strategies that work well across a wide range of possible futures (robust);
- Low cost strategies that if not needed will not have created a burden or harm (no regrets);
- Strategies that can be slowly implemented or changed as the future unfolds over time (flexible);
- Strategies to prepare for the possible worst case futures (hedge);
- Strategies that can be delayed until the future reaches a certain trigger point ("wait and see" contingency).

Adaptive Decision-making

Adaptive Decision-making (ADM) focuses on approaches to decision-making that are flexible and responsive to risk. It is a structured process "that enables systematic and efficient learning, aimed at reducing uncertainties" (Lee et al., 2018). The literature on ADM focuses primarily on infrastructure projects and natural resource, although modifications can make the framework

suitable for project-level planning processes. An example ADM framework is provided in Figure 35 (Lee et al., 2018).

ADM allows decision-makers to adjust plans and strategies as new knowledge and information about future risks and uncertainties are acquired throughout the life cycle of a project. Taking unknowns and uncertainties into consideration during the decision-making process reduces unintended consequences (Lee et al., 2018). Specifically, when an initial decision is made, information regarding future risks is limited. Rather than proceeding with this uncertainty, ADM integrates an iterative cycle at every step or interval of the decision-making process. At each interval, decisions are optimized based on evolving conditions and knowledge of future risks. This optimization limits and mitigates underestimation or overestimation of future risk and ensures adaptability and flexibility in the face of future risks (Lee et al., 2018).

Continuous risk reevaluation and updated decisions cultivate resiliency within an organization, community, or infrastructure system (Lee et al., 2018). Evolving conditions that ADM can address throughout a project's lifetime (specifically those affecting infrastructure systems and communities) are:

- Increasing hazard frequency and intensity due to global climate change
- Increasing exposure due to population growth and economic development in hazard-prone areas
- Changes in vulnerability due to material aging, deterioration, retrofit, and other physical alterations
- Evolving social expectations
- Technological progress
- Economic trends, including constrained resources over a project's life-cycle

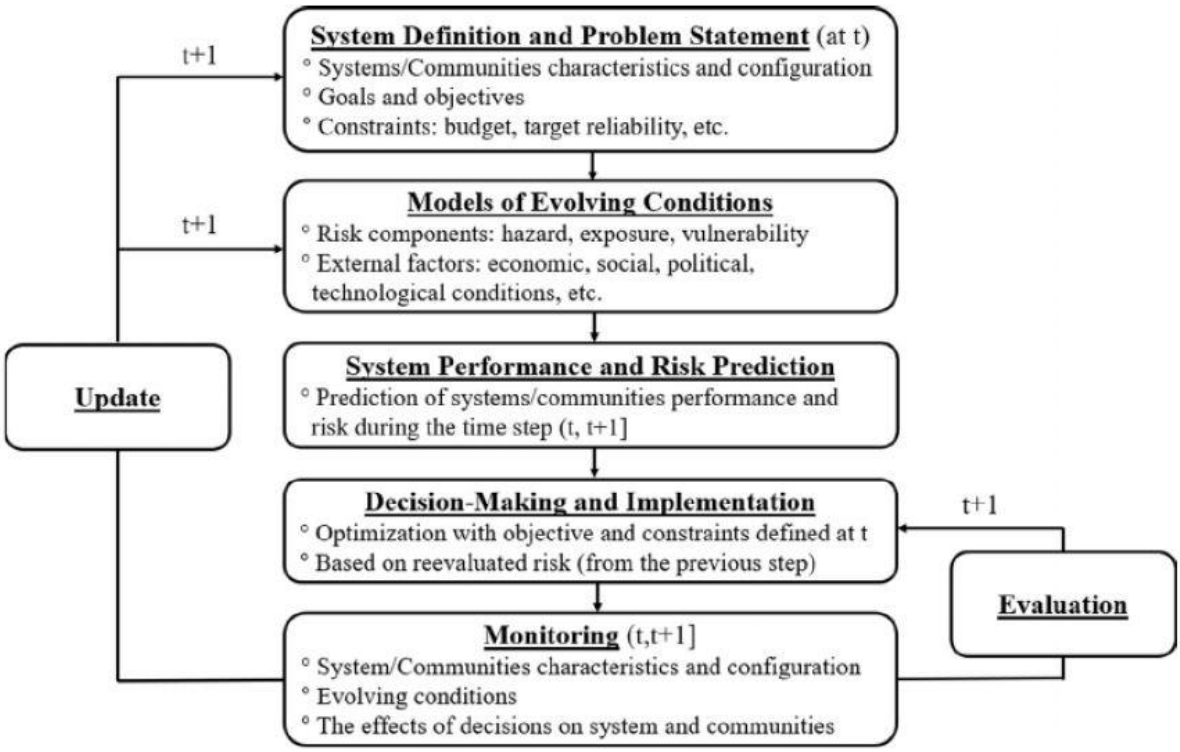


Figure 35. Proposed adaptive decision-making method

Source: Lee et al., 2018

The Adaptation Decision-Making Assessment Process (ADAP) is a risk-based framework used to assist decision-makers in determining appropriate project alternatives. ADAP also provides a framework for identifying the best approach to project design based on cost and benefits (FHWA, 2016). This framework was designed as a framework for assessing climate change related risks to assets and infrastructure, but given its flexible design and applicability, it can be used to account for a wide range of future risks and uncertainties related to various project types. The ADAP framework can be used in one of two ways:

1) To assess existing assets' sensitivity to future uncertainty
2) In designing new infrastructure projects in light of future uncertainties

ADAP is suitable for projects of various sizes. The ADAP framework can also be used to make system-level considerations as they relate to projects and uncertainty. Figure 36 depicts the ADAP process, it is importation to note that the framework highlights climate change risks, but these risks can be adjusted to accommodate for a variety of future risks and uncertainties in transportation projects.

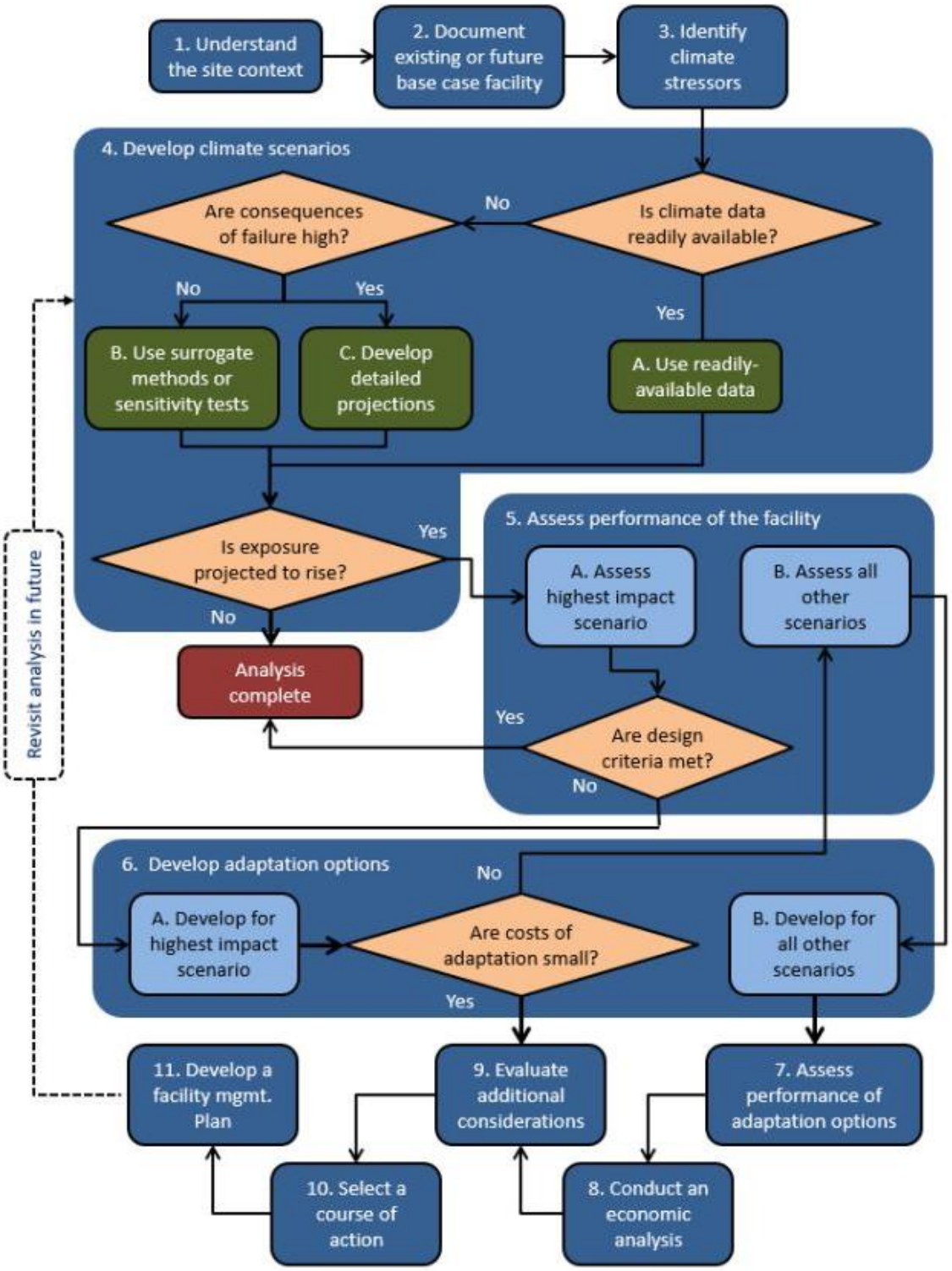


Figure 36. ADAP framework

Source: FHWA, 2016

Scenario Planning

Scenario planning explicitly acknowledges uncertainty. It allows agencies to evaluate priorities and goals, while challenging assumptions about the future. As stated by Lempert (2013), "scenarios exist so that decision makers and those who provide them with information can make statements about the future that claim less confidence than do predictions, projections, and forecasts." Scenarios can be used to identify the most uncertain drivers of change and plan for these uncertain drivers by putting them into a workable context.

Scenario planning can be conducted in a variety of ways that suit the individual needs of any organization or agency. A typical framework is shown in Figure 37 (FDOT, 2018a). Identification of change factors, consideration of possible futures, and proactive adaptation to trends that have internal and external, as well as short- and long-term effects are key aspects of the scenario planning process (Quay, 2018). Agencies can thereby envision a range of possible future alternatives and create guiding principles for these potential alternative futures. Chapter 4 explores scenario planning best practices and methods in further detail for screening and analysis of the FTP scenarios.

Figure 37. Scenario planning framework

Source: FDOT, 2018a

Performance-Based Planning and Programming

Performance-based planning and programming (PBPP) uses information on past and anticipated future trends, along with progress toward goal achievement, to inform investment decisions (Twaddell et al., 2016). Coupling scenario planning with PBPP ensures that uncertainty and decision-making surrounding that uncertainty is addressed throughout the planning process. As Twaddell et al. (2016) suggest, "scenario planning can be used to improve the PBPP process by explicitly addressing uncertainties and by encouraging consistency among goals, objectives, and metrics as they are applied throughout each phase, from visioning and plan development through project selection and ongoing performance evaluation" (p. 16).

Figure 38 offers an example of such a framework. By exploring multiple future scenarios, agencies can make a well-informed selection of preferred alternative futures that have the best potential to support agency goals and objectives, while meeting performance targets and anticipating future risk and uncertainty (Twaddell et al., 2016). The process helps agencies and stakeholders in "defining a shared vision and performance goals, analyzing trade-offs between possible strategies, assessing the impacts and implications of external driving forces, and identifying investment priorities that advance desired outcomes" (Twaddell et al., 2016).

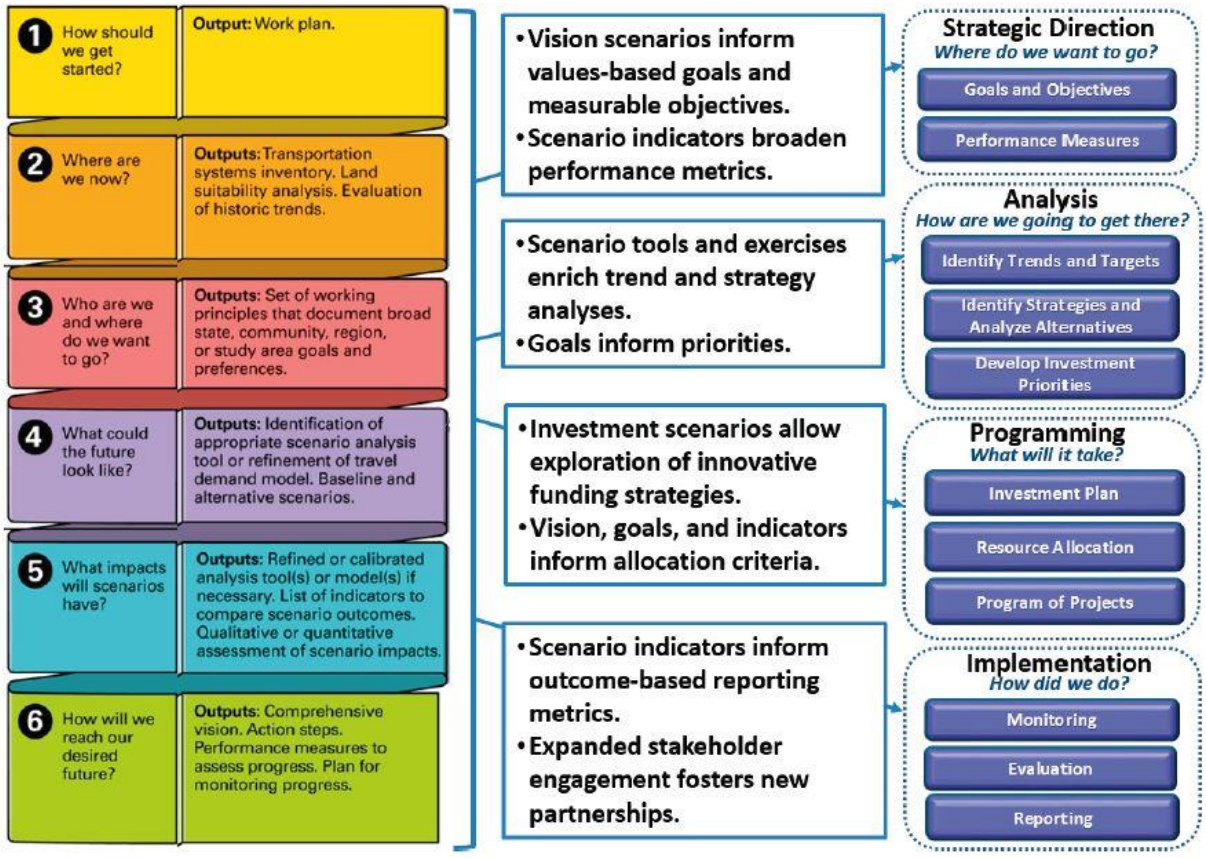


Figure 38. Applications of scenario planning to PBPP

Source: Twaddell et al., 2016

Risk Treatment Plans

Risk treatment plans for consequence management are embedded in the New Zealand risk management process. Once the context is established and risks are identified, a risk analysis is conducted. The risk analysis includes an analysis of existing controls, a description and rating of the consequences of risk, and a description and rating of the likelihood of the risk. Ratings are assigned based on professional judgement and by consensus. Appendix C shows an example consequence-rating table.

After risks and consequences are analyzed and evaluated, risks are assessed for a specific treatment. Treatment plans are developed to identify treatment types and treatment actions

for opportunities and threats. Treatment types are based on the risk score and grouped into three categories to address opportunities and threats, active strategies for opportunities, and active strategies for threats. The risk score is used to select a treatment type. Treatment actions include resources, timing, responsibilities, and monitoring and reporting requirements. Progress is then recorded and summarized in a risk register. A sample risk treatment plan is shown in Appendix C.

Project Risk Management

According to Khadka (2015), Project Risk Management (PRM) is an active and forward-looking method used to accomplish the following objectives:

- Identify foreseeable risk events in a project
- Analyze the potential impact of each risk event on a project
- Prioritize risks based on the severity of impact through the use of a Risk Matrix and Risk Register
- Create problem solving strategies in advance to mitigate risk impacts
- Monitor each risk event until it is averted, mitigated, or resolved.

Effective PRM should identify individual risk events within the project, provide an indication of overall project risk exposure, and manage risks appropriately (Hillson, 2014). To accomplish this goal, project risk management should answer the following questions:

1) What we are trying to achieve?
2) What could go wrong? And how?
3) What opportunities exist and how can they be realized?
4) What do we need to do to mitigate threats and seize opportunities?
5) How were answers to the above questions tested and validated?
6) Who needs to know or be involved?
7) How quickly do we need to respond?
8) What resources are required?

The PRM process includes five, recurring steps (Figure 39):

1) Risk planning
2) Risk identification
3) Risk analysis
4) Risk response planning
5) Risk monitoring and control

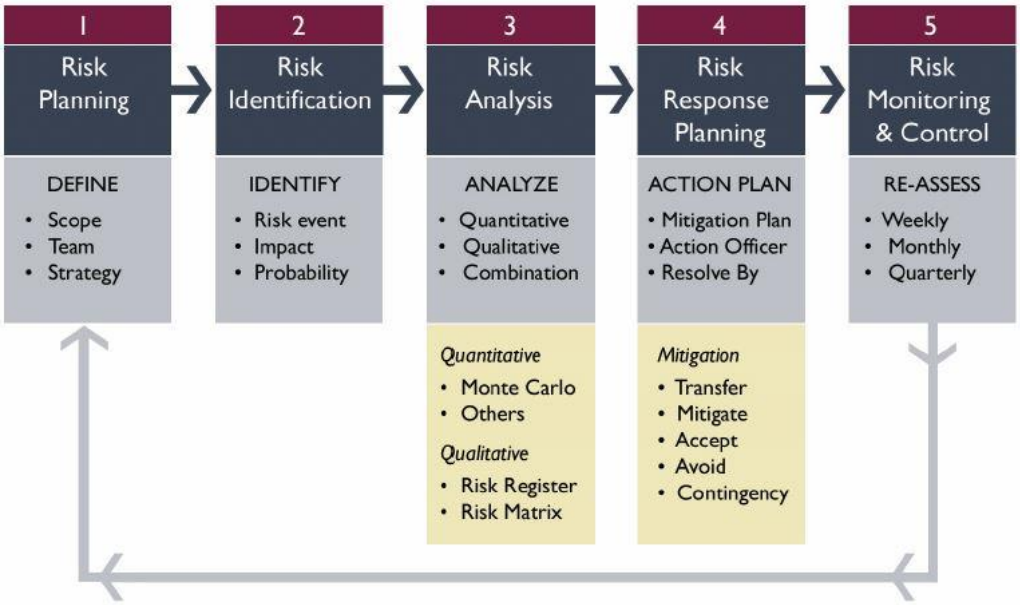


Figure 39. Project risk management model

Source: Khadka, 2015

Risk management should be ongoing throughout a project's lifetime; new risks are added to the PRM process as they become apparent. Communication between all parties involved in the project is necessary for PRM to be effective.

Ward and Chapman (2003) suggest moving away from project risk management and instead practicing project uncertainty management. This approach aims to bring a focus to project-related uncertainties and resulting management issues instead of limiting management issues to risks.

Options Approach to Risk Management

Brand et al. (2000) proposed a qualitative "options" approach to evaluating risk in the context of metropolitan long-range transportation planning (Figure 40). The approach focuses on the evaluation of project alternatives and aims to systematically account for uncertainties that projects face before investment decisions are made to help avoid or reduce a harm or loss to the agency (Brand et al., 2000).

Table 12 offers insight into two key steps of the options approach to risk management in transportation planning (Brand et al., 2000):

1) Identification of risk factors.
2) Development of risk mitigation options based on learning and flexibility in project timing and definition.

This process would occur both before and after a project is implemented and would include:

1) Low cost actions that preserve the option to wait.
2) Options for learning that reduce uncertainty as more information becomes available.
3) Options that offer flexibility to capitalize on new information as uncertainty is resolved over time.

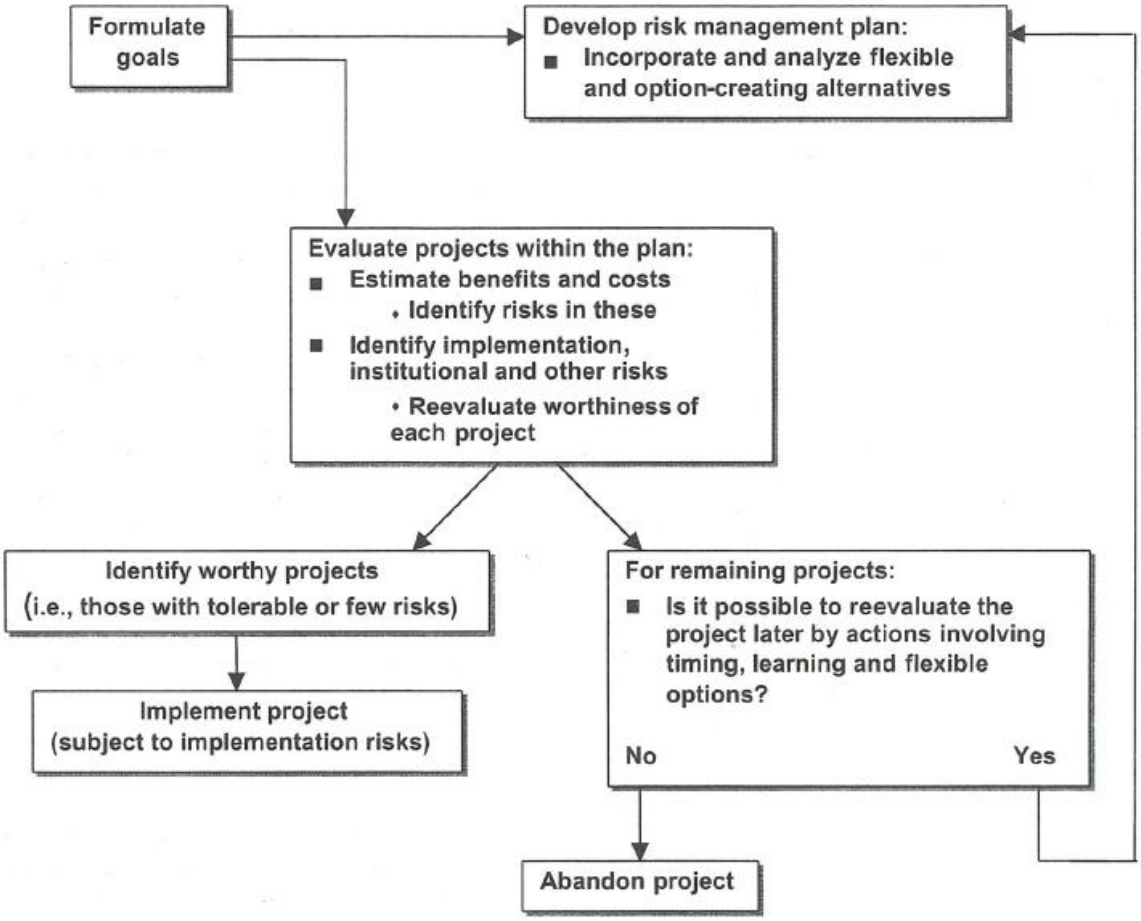


Figure 40. Options approach to risk management in transportation planning

Source: Brand, Mehndiratta, Parody, 2000

Table 12. Example of Options Approach to Risk Management

Risk Category	Source(s) of Risk	Risk Management Options
Before a Project Is Implemented		
Political: Short Term	• Party in power changes, reducing/eliminating support for project	Incremental planning, building coalitions, staged implementation
	• Impacted neighborhoods oppose project at public hearings and elsewhere, forcing design changes with cost and market impacts	Same
	• Natural or economic events occur (e.g., earthquakes) changing spending priorities	Same
Political: Long Term	• Public opinion and values change (e.g., on environmental or community disruption), changing valuation of project impacts	Incremental planning, building coalitions, staged implementation
	• Laws governing project design change (e.g., taking of parks, compensation for takings), changing designs, costs and other outcomes	Same
	• Promises made to project opposers have unintended consequences (e.g., cost and market risks)	Same
Forecasting (Market)	• Validity of input assumptions regarding the future (growth rates, land use patterns, energy costs, values of time, economic (including inflation) and wage projections, etc.)	Incremental planning, sensitivity analysis, staged implementation
	• Validity of assumed relationships	Same, plus additional data collection and model development
	• Validity of modeling techniques (ecological fallacies, aggregate versus disaggregate modeling needs and techniques)	Methodological research
Funding (Financial)	• Expected stream and form of funding does not appear	Building coalitions, develop plans with smaller discrete phases
	• Reductions in funding levels	Same
	• Constrained funding, e.g., earmarked funding may come with riders that impose unexpected costs or unintended consequences that eliminate alternatives or force concentration on a few aspects of the original proposal	Same
Litigation	• Possible litigation risks at the planning stage include – Environmental and air-quality interests under 1990 Clean Air Act regulations (e.g., MTC vs. Sierra Club) – Mobility impaired interests under ADA regulations – Racial/social class action suits brought under civil rights or constitutional grounds (e.g., LA rail vs. bus lines)	Additional consideration and forecasts of impacts required by relevant statutes, building coalitions
	• Lowered ridership and revenue forecasts and higher cost estimates to lessen risk of future liability on privately financed projects	Legislation to limit or clarify liability
Cost (including Time)	• Delays, cost overruns in construction/ installation	Additional engineering and cost estimation, writing appropriate contract language, turnkey contracts
	• Litigation by losing bidders for construction contracts (New Jersey ETC contracts, Metro vs. SmartRoutes in Cincinnati)	Transparency in bidding process
Technology	• Innovations in technology that make project prematurely obsolete	Staged implementation

(Continued on next page)

Risk Category	Source(s) of Risk	Risk Management Options
After a Project Is Implemented		
Market	• Low ridership/travel volumes, low levels of use	Staged implementation, marketing and advertising, pricing flexibility
Operational Performance	• System doesn't perform as planned or performs in an unsafe manner (particularly relevant with 'new'/ untested technologies such as computer software, software bugs, compatibility issues)	Additional prototype testing, additional engineering development, flexible procurement practices that allow for staged deployment, contractual language based on performance.
	• Travel volumes lead to unanticipated congestion	Incremental planning, staged implementation
Operating and Maintenance Costs	• Operating and maintenance costs higher than expected	Same as above
Institutional/ Organizational	• Possibilities of labor-management disputes etc.	Long term contracts, BOT contracts
	• Inability to manage/operate project effectively	Same
Political: Long Term	• Special interest legislation such as ADA, the Clean Air Act etc.	Staged implementation
	• Change in the regulatory structure (deregulation) of upstream suppliers, or downstream consumers (such as changes in airport capacity requirements with air deregulation)	Same
Financial	• Lower levels of subsidy forthcoming	Staged implementation, long-term contracts
Political: Short Term	• Change in public (and elected official) attitudes on issues such as toll roads, congestion pricing, etc.	Staged implementation, building coalitions
Liability	• Litigation over project outcomes not being as planned	Legislation to limit or clarify liability, incremental planning, staged implementation

Source: Brand, Mehndiratta, Parody et al., 2000

Risk Management Tools

This section offers a sample selection of tools that can be used by state transportation agencies to facilitate planning and project level risk management for future uncertainty. Tools include Critical Infrastructure Networks, Community Emergency Risk Assessment (CERA), decision trees, sketch planning, spreadsheets, and risk registers.

Critical Infrastructures: Relations and Consequences for Life and Environment (CIrcle)

CIrcle aims to incorporate the cascading effects of failed critical infrastructure into adaptation planning. The tool engages stakeholders to assess the vulnerability of critical infrastructure and identify the consequences of failure. Results are used to model and quantify the impacts of flooding and develop adaptation measures to make critical infrastructure and communities more resilient.

The CIrcle tool was used in Broward County, Florida. The process included two stakeholder workshops. The first workshop explored the critical infrastructure networks by identifying the impact of flood events on critical infrastructure, identifying the relationship between different critical infrastructure, and classifying the relationships (Figure 41). The second workshop used findings from the first workshop to conduct a detailed assessment of cascading impacts. First, second, and third order cascading impacts of power outages were identified. The compound cascading impact from a failed road network were also identified. Results from breakout session group 1 and group 2 are shown in Figure 42. The CIrcle project for Broward County and additional resources including workshop details and findings to date can be found at http://circle-cifre.nl/index.php.

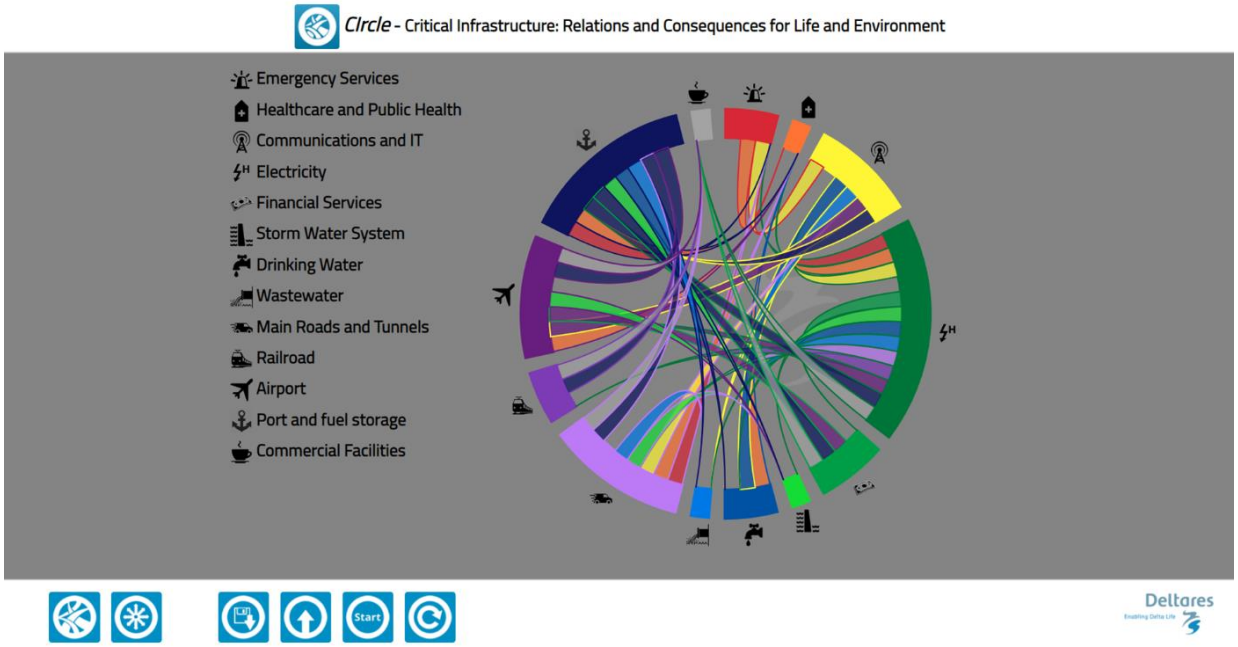


Figure 41. Critical infrastructure relationships

Source: Jeuken et al. (2019)

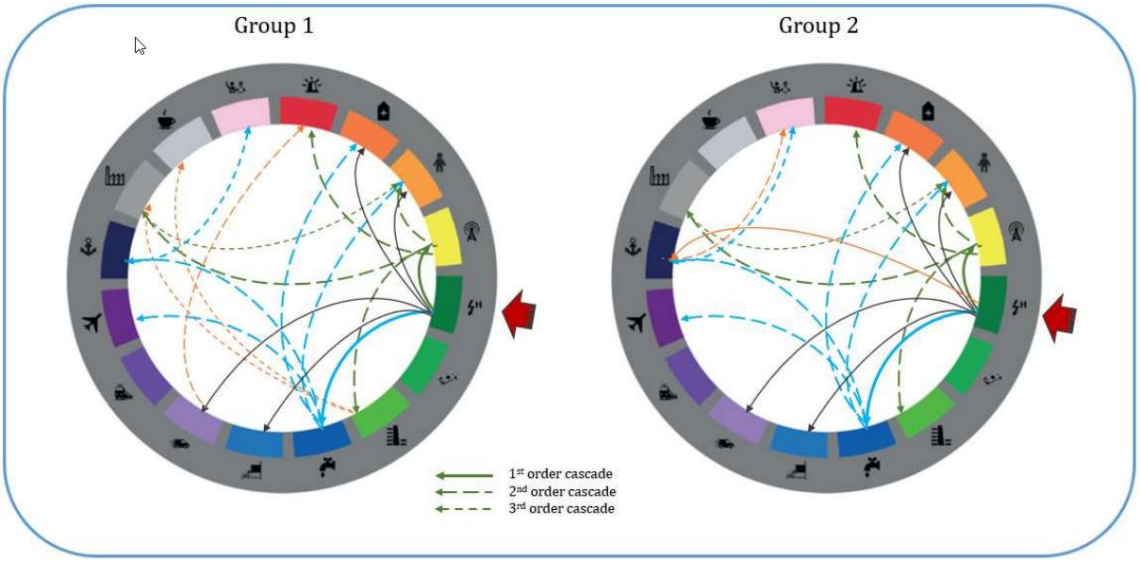


Figure 42. Cascading impacts of power outages

Source: Jeuken et al. (2019)

Community Emergency Risk Assessment

The Community Emergency Risk Assessment (CERA) is a framework developed by the Victoria State of Emergency Service to improve safety and resilience. The CERA tool, a downloadable excel document, allows municipal governments to identify and prioritize hazards and risks, and assess impacts and consequences based on the vulnerability or exposure of the community or its functions (Figure 43). The tool and detailed instructions can be downloaded via the Victoria State Emergency Service website https://www.ses.vic.gov.au/em-sector/em-planning/risk-assessment.

Figure 43. Community emergency risk assessment

Source: Victoria State Emergency Service, 2014

Decision Trees

Decision trees are useful tools to achieve robustness and resiliency in the decision-making process. Dewar and Wachs (2008) describe decision trees as structures composed of nodes and connection between nodes (Figure 44). The process of using a decision tree is as follows (Dewar & Wachs, 2008, p. 11):

> "For a given decision, the tree starts with the basic options as branches from the first node. Each of these options rests on uncertainties and subordinate decisions. From each node representing subordinate decisions, the analyst draws out lines that represent options. From each option, the analyst draws out possible outcomes from that decision. This diagram continues until all important subordinate decisions and all relevant options are diagrammed in the tree structure."

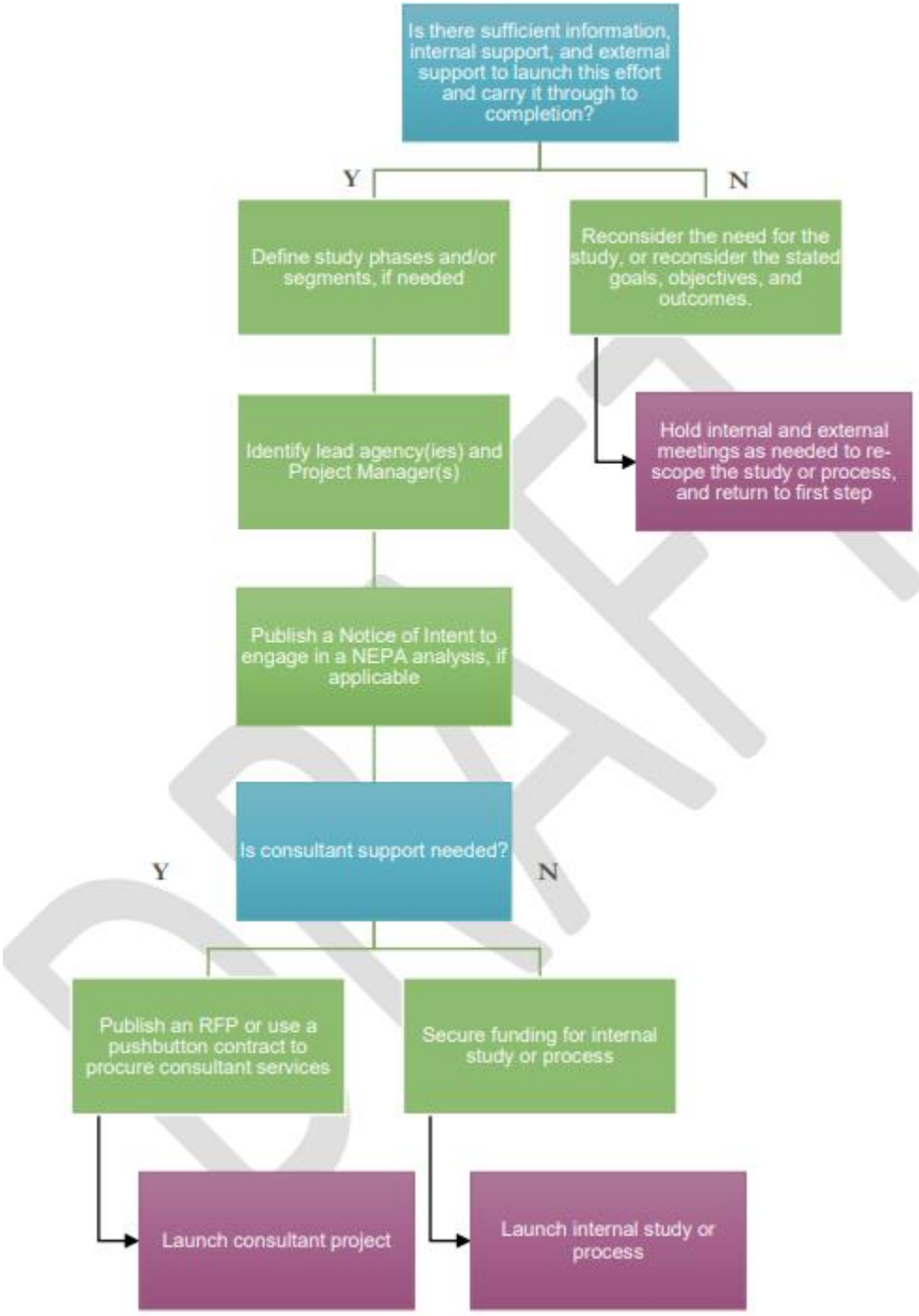


Figure 44. FDOT conceptual decision tree

Source: FDOT, 2018b

Florida Sea Level Scenario Sketch Planning Tool

The Florida Sea Level Scenario Sketch Planning Tool (Figure 15) uses flood projections from the U.S Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA), in conjunction with GIS layers and LiDAR data to identify transportation

infrastructure that is susceptible to current and future flood risks (University of Florida GeoPlan Center).

At the project level, this web-based, interactive tool can be used to determine current and future sea level rise projections in relation to the location of proposed projects. This tool can determine if a project will be affected by sea level rise and flooding, identifying when and to what extent. The tool can also be used to evaluate existing infrastructure at risk to sea level rise and flooding to implement projects that mitigate projected impacts. Detailed instructions and the sketch tool interface can be found online on the University of Florida's GeoPlan Center's website (https://sls.geoplan.ufl.edu/view-maps/).

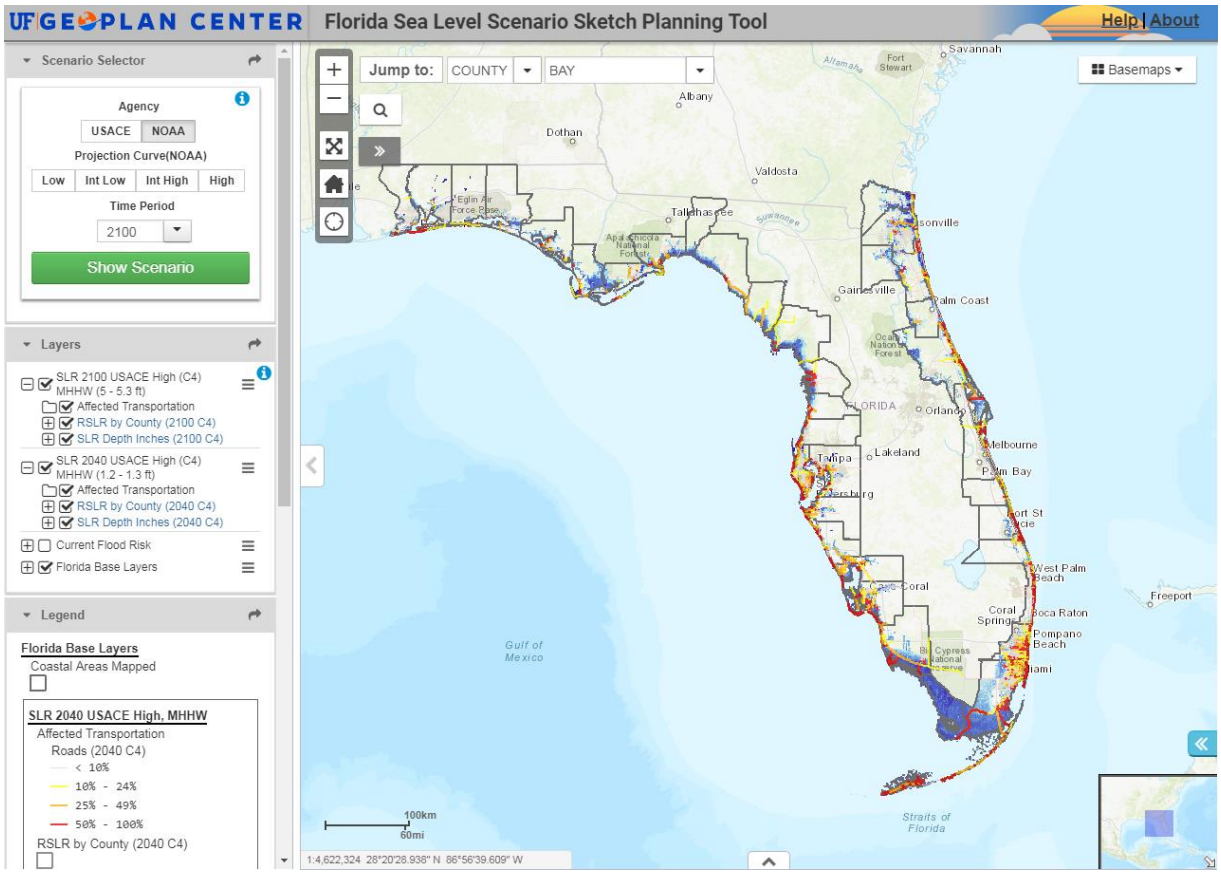


Figure 45. Florida sea level scenario sketch planning tool

Source: GeoPlan Center, University of Florida

Qualitative Risk Assessment Spreadsheet

Designed by the Washington State Department of Transportation's (WSDOT) Strategic Analysis and Estimating Office (SAEO), the Qualitative Risk Assessment Spreadsheet is a tool to evaluate the likelihood and potential impact of project-level related risks. The spreadsheet, a downloadable excel file, categorizes risks from the RBS and allows the user to add descriptive information about the risk. Information includes the risk status, type, number, the phase of the project that the risk will impact and the date that the risk was identified. The spreadsheet also takes into account the qualitative nature of the risk impact (from very low to very high) and risk

probability (from very low to very high) to plot the qualitative risk level on a matrix (see Figure 16). Strategies and actions, as they relate to project risks, are determined based on the qualitative analysis of the risk. Lastly, the spreadsheet offers space to add comments related to risk monitoring and control. As changes in risks occur or new risks are identified the spreadsheet can be updated. More information on the tool and other information on project risk management can be found on WSDOT's website http://www.wsdot.wa.gov/Design/SAEO/.

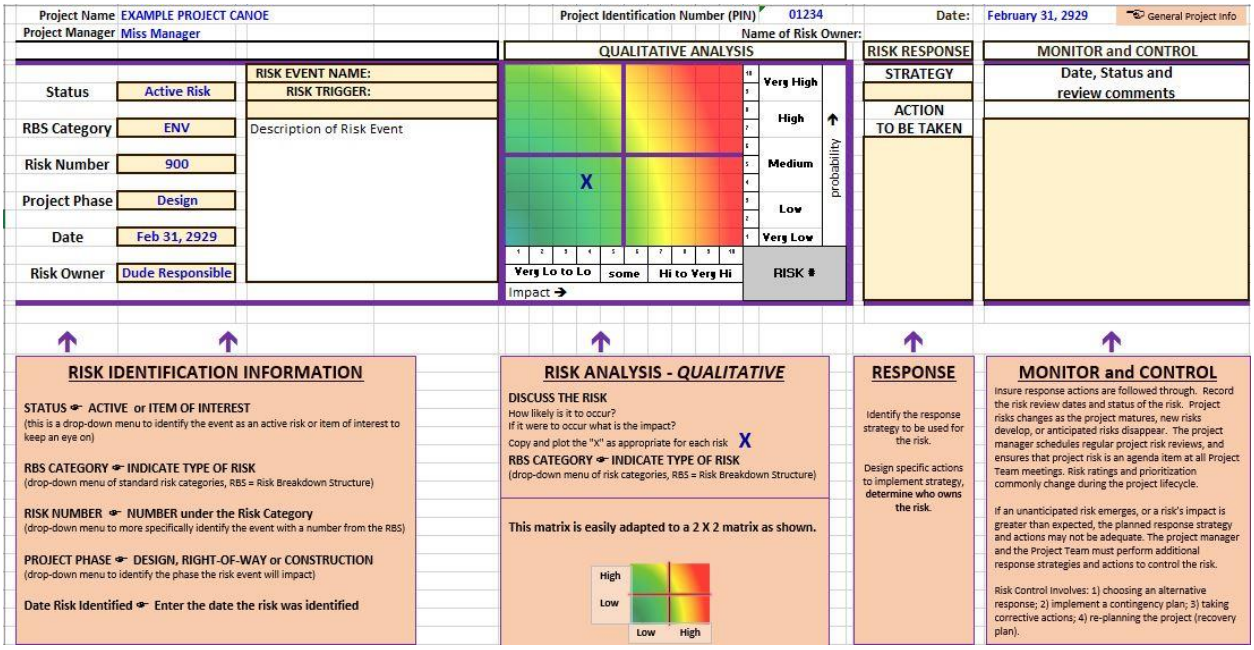


Figure 46. Qualitative risk assessment spreadsheet example

Source: WSDOT, n.d.

Risk Registers and Checklists

Risk registers describe the characteristics of risks, such as the likelihood of risk occurrence, the impact or consequences of risks, the root causes of risks, affected objectives due to risks, and overall risk rating (Curtis et al., 2012). In addition to the aforementioned contents, risk registers can also include risk triggers, risk responsibility, and mitigation strategies. Risk registers are flexible in that they can be used extensively or for guidance in the risk management process, depending on an agency's specific needs. Sample risk registers for each of FDOT's seven policy goals can be found in Appendix D.

Similar to risk registers, although simpler, risk checklists are useful tools for managing risk at the enterprise, program, and project level. Risk checklists should be created early in the project development process and reviewed throughout the project as a part of an auditing process. Risk checklists are also useful at the end of the risk identification process to ensure that no common risks are overlooked once project-specific lists have been identified (Molenaar et al., 2010). Contents of the risk checklist are based on judgement or past experience or records (Molenaar et al., 2010; Proctor et al., 2016). Due to their simplicity, risk checklists should not be the sole tool for risk identification (D'Ignazio, 2011).

The risk checklist seen in Table 13 was developed for the New York State Department of Transportation (NYSDOT). Risk factors are categorized by project development risks, external risks, environmental risks, project management risks, right-of-way risks, and construction risks. Risk factors are checked if they have the potential to affect cost, schedule, scope, or quality. The risks identified in this example are specific to project delivery, but provide a clear illustration of the process to develop the checklist.

Table 13. Potential Risks List

POTENTIAL RISKS LIST

Key: When multiple checkmarks apply, red √ indicates highest priority

PROJECT DEVELOPMENT RISKS				
RISK FACTOR	**POTENTIAL FOR IMPACT ON**			
	COST	**SCHEDULE**	**SCOPE**	**QUALITY**
Design incomplete at PS&E				√
Unexpected geotechnical or groundwater issues	√	√		
Changes to materials/geotechnical/foundation		√		
Foundation and geotechnical tasks (foundation drilling and material testing) not identified and included in project workplan		√		
Inaccurate assumptions on technical issues in planning stage			√	
Additional survey required		√		
Bridge site data incomplete to DES		√		
Existing structures planned for modification not evaluated for seismic retrofit, scour potential and structural capacity	√	√		
Condition of the bridge deck unknown	√			
For projects involving bridge replacement, bridge carries traffic during staging causing traffic delay				√
Design changes to alignment, profile, typical cross section, stage construction between Advance Planning Study and the Bridge Site Submittal		√		
Unforeseen design exceptions required		√		
Consultant design not up to Department standards				√
Unresolved constructability review items	√			
Complex hydraulic features				√
Incomplete quantity estimates	√			
New or revised design standard	√			
RR Agreements not obtained on time		√		
Special railroad requirements not identified during preliminary design		√		
Utility Agreements not obtained on time		√		
Construction staging more complex than anticipated	√	√		
Unforeseen aesthetic requirements	√			
Contextual Assessment incomplete			√	
Unresolved Public Involvement Issues		√	√	
Other Design Risks				

Source: New York State Department of Transportation, 2009

Chapter 4
Risk Assessment Tools for Long Range Planning

The research team applied methods from the field of risk management to develop tools to assess risk in a long-range transportation planning context. The risk register analyzes risk in relation to statewide planning goals and objectives as reflected in the FTP Vision and Policy Elements. The asset screening tool evaluates the susceptibility of Florida's transportation system and assets to risk events. Finally, an alternative future screening tool assesses the sensitivity of the FTP Vision Element alternative futures to future risk. This chapter presents a description of each tool and conceptual examples of their use.

Risk Register Tool

Through a brainstorming process, specific risk events (consequences) were first identified relative to areas of uncertainty detailed in Chapter 2. These risk events were then categorized based on their relevance to adopted statewide planning goals and objectives, as expressed in the FTP Vision and Policy Elements.

Each risk event was further examined based on the likelihood of the risk occurring, magnitude of its potential consequences, and the level of vulnerability to experiencing those consequences. Possible timeframes for each risk event were also identified, along with general consequence management strategies. Scales for likelihood, consequence, and vulnerability were developed for this purpose, using approaches identified in Chapter 3, and applied to each risk event. The following are the scales applied in the analysis.

Likelihood – *probability of a risk event occurring.*

1 Remote ≤ 1%:
2 Unlikely > 1% to < 25%
3 Possible > 25% to < 50%
4 Probable > 50% to < 95%
5 Almost Certain ≥ 95%

Consequences – *magnitude of impact of a risk event on transportation planning goals.*

1 Negligible: Little or no impact on progress toward planning goals
2 Low: Minimum impact with regard to planning goals
3 Moderate: Some impact with regard to planning goals
4 High: Greatly impacts progress toward planning goals
5 Extreme: Reverses progress toward planning goals

Vulnerability – *the susceptibility of assets, systems, and/or services to a risk event.*

1 Extremely low: Extremely low susceptibility to risk
2 Low: Low susceptibility to risk
3 Moderate: Some susceptibility to risk
4 High: High susceptibility to risk

5 Extremely high: Extremely high susceptibility to risk

Timeframes were identified based on the literature and assigned to each risk event. As shown below, the "timeframe" represents the time period that a risk event is expected to occur or to have the most pronounced effects.

Time Frame – *the estimated time period that a risk event will begin or in which its impacts are expected to be most pronounced.*
(C)urrent: 2010-2020
(E)merging: 2020 – 2030
(N)ear Future: 2030-2040
(F)ar future: 2040-2070
(U)ncertain: time frame of risk event is unknown

For purposes of the analysis, "likelihood" was defined as the probability of a risk event occurring in a given timeframe (the likelihood is estimated based on when the risk event is projected/expected to be most pronounced), "consequences" are the risk event's impact on the progress of the agency's goals, and "vulnerability" is the susceptibility of assets to the risk event. Using the scales developed for likelihood, consequence, and vulnerability, the following risk formula by Herrera et al. (2017) and Machado-León & Goodchild (2012) was then adapted to calculate overall risk as the product of each variable:

Risk Level = Likelihood x Consequence x Vulnerability

Next, the possible scores were grouped into five (5) risk levels and five (5) consequence categories. Risk events with the lowest score (i.e., 1 - 24) were considered of low risk or lessor urgency or priority, whereas risk events that score highest (i.e., 100 – 125) were considered critical and to be acted on immediately. Each risk level was also color-coded creating a heat map to illustrate risk level and relative urgency or priority, using the following scale.

Overall Risk– *product of likelihood, consequence, and vulnerability.*
1 – 24 Low Risk (Not a priority)
25 – 49 Moderate Risk (Low priority)
50 – 74 High Risk (Medium priority)
75 – 99 Extreme Risk (High priority)
100 – 125 Critical (Immediate action needed)

Finally, possible consequence management approaches were assigned to each risk event as suggestions regarding general ways Florida DOT might respond to that risk event. The following criteria were applied for that purpose.

Consequence Management – *proposed approaches to manage specific types of risk events.*
Threats

- Avoid: Take proactive action to ensure the probability or impact of a risk is eliminated.

- Mitigate: Prepare contingency plans to mitigate the consequences of risks that cannot be eliminated or controlled due to cost or other reasons.
- Transfer: Shift responsibility to another party with authority to address the risk.
- Coordinate: Collaborate with other agencies or private sector to address potential risks.

Opportunities

- Exploit: take action to ensure the benefit of an opportunity is realized, ensuring a positive impact.
- Share: take action with another party who is able to maximize the potential benefits.
- Enhance: take action to strengthen the cause of, or reinforce the conditions that result in an opportunity; trigger conditions are proactively targeted and reinforced.

Results of the FTP risk management analysis were presented in the form of a risk register and are provided in Appendix D. Supplementing the risk register is a table exploring the susceptibility of specific assets to various risks. The methods and tool developed for this purpose could be further refined and adapted for use in both long range planning and project screening.

Asset Screening Tool

For purposes of screening, transportation assets were first categorized using approaches found in Florida at both a regional and state level. Hillsborough Metropolitan Planning Organization (MPO), for example, describes assets for the purposes of vulnerability assessment as "infrastructure vital to Hillsborough County's needs" (Hillsborough MPO, 2014, p.5). Asset types identified in the assessment consist of (Hillsborough MPO, 2014):

- Roadways
- Centerline miles of paved roadway, including principal arterials
- Miles of pavement markings
- Miles of sidewalks
- All intersections, including signalized ones
- Signs
- Pedestrian ramps
- Storm mains and culverts
- Transit centers
- Rail
- Intermodal facilities
- Education facilities
- Air Force base
- International airport
- Traffic Analysis Zones (TAZs)
- Transit routes
- Evaluation routes
- Bridges
- Power plants
- Medical centers
- Seaports

FDOT identifies transportation facilities of strategic importance to the state's economy and mobility as the Strategic Intermodal System (SIS) (Meyer, 2007). The types of facilities or assets in the SIS are shown in the bulleted list below. Pavement and bridges are two subcategories in FDOT's priorities (Meyer, 2007). Further expansion of the management system is underway to include safety, transit, intelligent transportation systems (ITS), and culverts, among other assets (FDOT, 2015a).

- Commercial service airports

- Spaceports
- Deepwater seaports
- Rail freight terminals
- Interregional passenger terminals
- Rail corridors
- Waterways
- Highways
- Intermodal connectors

Florida's Turnpike Enterprise has its own asset management system known as TEAMS for management of assets that include "pavements, roadways, facilities…, bridges, drainage systems, and safety conditions" (Meyer, 2007, p.2-14). Table 14 identifies and categorizes various FDOT transportation assets. Figure 47 illustrates considerations relative to these assets.

Table 14. FDOT Assets by Category

Highway Assets	Structure Assets	Safety Assets	Multimodal Assets	Vehicle Assets	Technological Assets	Real Estate Assets
Pavement Interchanges (including ramps) and intersections Corridors	Bridges and Tunnels Culverts Mechanically Stabilized Earth (MSE) retaining walls Ditches Catch basins Under/edge drains	Barriers, (e.g., guard rails) Signals Signs Lighting systems (e.g., fixtures, poles, controllers) Pavement markings (e.g., raised markers stripping, rumble strips stripes, sidewalks, ADA assets)	Railway yards and stations Ports Bikeway, sidewalk, and trails Airports Intermodal Facilities Weighing stations	Transit fleet Incident Response Vehicles (IRV), (e.g., FDOT Road Ranger fleet)	Traffic management centers Intelligent Transportation Systems (ITS), (e.g., variable message signs, toll-by-plate, signal timing)	Rights-of-way Vacant parcels and government-owned lands Rest areas and welcome centers

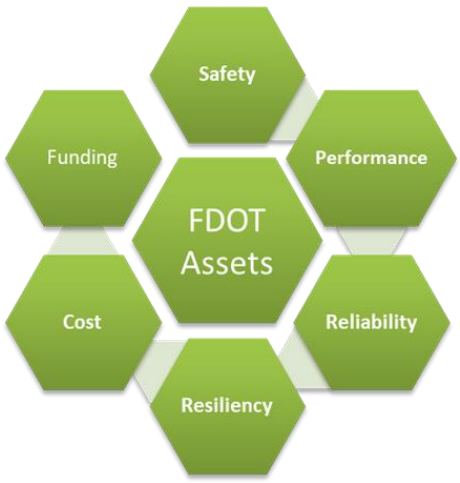


Figure 47. Important considerations related to FDOT assets.

The susceptibility of transportation system assets to particular risk events is implicit in the measure of vulnerability. Table 15 explores the relationship between assets and risk for two key areas of disruption – technology and natural hazards/climate.

Table 15. Example Transportation Asset Vulnerability Table

Asset Categories	Assets	Risks								
		Technology				Natural Hazards/Climate				
		Automated and Connected Vehicles	Ridesourcing and Ridesharing	Alternative fuels and Zero Emission Vehicles	Hyperloop	Sea level rise	Extreme temperature	Increased precipitation and flooding	Wildfires	Extreme weather events
Highway	Pavement									
	Interchanges and intersections									
	Corridors									
Structure	Bridges and tunnels									
	Culverts									
	Mechanically stabilized earth (MSE) retaining walls									
	Ditches									
	Catch basins									
	Under/edge drains									

Not vulnerable	○
Somewhat vulnerable	◑
Highly vulnerable	●

Alternative future Screening Tool

Another potential application of the risk register tool is to inform a screening of alternative futures for robustness relative to uncertainty. Robustness may be generally defined as the capability to perform without failure under a wide range of conditions. Specifically applied to uncertainty, robustness is defined as "a decision that performs acceptably well under a wide range of plausible future conditions" (Borgomeo et al., 2018).

For the purpose of screening an alternative future, one would need to evaluate the sensitivity or susceptibility of an alternative future element to a specified threat or its ability to leverage a specified opportunity. Given the limited details describing the alternative futures found in the FTP Vision Element, one method for screening those alternative futures is to examine the sensitivity of each alternative future, as conveyed in the "Could We" statements of the FTP, in relation to each risk event identified in Chapter 2. Doing so would address both the aspirations of the alternative future and the long-range planning goals and objectives it embodies.

An example ranking system for sensitivity can be seen below:

<u>Threats</u>

1 Highly susceptible to threat
2 Partially susceptible to threat
3 Not susceptible to threat

<u>Opportunities</u>

1 No potential to leverage the opportunity
2 Weak potential to leverage the opportunity
3 Strong potential to leverage opportunity

Two robustness scores may be calculated for screening:

(1) A total possible robustness score (the product of the total number of alternative future elements for each alternative future, the total number of risk events, and the maximum possible sensitivity score for any given alternative future element under any risk), and

(2) A total actual robustness score (the sum of all sensitivity scores for each alternative future element in relation to each risk event).

The total robustness score is then reflected as a percentage calculated using the formula below:

$$\text{Total robustness percentage} = \frac{\text{Total actual robustness score}}{\text{Total possible robustness score}} \times 100$$

This percentage score accounts for the varying number of alternative future elements for each alternative future and allows for an equivalent evaluation and comparison of robustness across all alternative futures for the purpose of prioritization and decision-making.

For example, the total possible robustness score for the *Global Trade Hub* alternative future as it relates to a select few risk events (8 threats and 9 opportunities) is 144 for threats and 162 for opportunities. That number is determined by multiplying 8 (the number of threats provided) or by 9 (the number of opportunities provided), by 3 (the total possible sensitivity score for any given alternative future element per risk event), and by 6 (the number of alternative future elements) as seen the in the formulas below:

Threats

$$\text{Total possible robustness score} = 8 \times 3 \times 6 = 144$$

Total actual robustness score = 98

$$\text{Total robustness percentage} = \frac{98}{144} \times 100 = 68\%$$

Opportunities

$$\text{Total possible robustness score} = 9 \times 3 \times 6 = 162$$

Total actual robustness score = 102

$$\text{Total robustness percentage} = \frac{102}{162} \times 100 = 63\%$$

The robustness percentage is a broad gauge of the susceptibility of an alternative future to an identified threat, or how well an alternative future may accommodate or take advantage of an opportunity. A high robustness percentage would indicate that the alternative future is not susceptible to the majority of the identified threats or it offers potential to take advantage of the majority of the identified opportunities; hence, the alternative needs little to no improvement or changes to address future risk and uncertainty. A very low robustness percentage indicates that the alternative future may be highly susceptible to the identified threats or may not adequately take advantage of the identified opportunities. The alternative future may need to be modified to clearly address future risk and uncertainty. The robustness percentage scale is defined below:

Robustness Percentage – *How well an alternative future will perform under specified threats and opportunities. Total actual alternative future robustness score divided by total possible alternative future robustness score.*

- 0% - 33%: The alternative future is highly susceptible to the identified threats/has no potential to leverage identified opportunities; alternative change needed.
- 34% - 67%: The alternative future is somewhat susceptible to identified threats/ weak potential to leverage identified opportunities; alternative future improvement needed.

- 68% to 100%: The alternative future is not susceptible to identified threats/has a strong potential to leverage identified opportunities; minimum to no alternative future improvement needed.

Table 16 illustrates a preliminary example of this conceptual alternative future screening process, using the *Global Trade Hub* alternative future and a select few threats and opportunities relative to the FTP planning goal of safety and security. Complete results for this analysis can be found in Appendix E.

A challenge faced by the research team in conducting this analysis is the lack of detail specific to each alternative future, the broad nature of the "Could we" statements, and the discretionary nature of the sensitivity analysis. Other details, such as relevant plan policies and strategies, may be necessary for this analysis to be meaningful in guiding stakeholder discussions. Should this approach prove to have merit, it could be adapted as necessary and further expanded for use in alternative future and scenario screening, along with other methods. It may also aid in scrutinizing individual risk events in more depth in the context of each alternative future.

Table 16. Conceptual Example of Alternative future Screening Relative to Risk Events

Alternative future: Global Trade Hub (Safety and Security)
Total Possible Score: Threats 144; Opportunities 162

		Continue to deepen harbors, extend runways, and expand terminals to handle larger ships and planes	Improve road and rail connections to major seaports and airports	Improve long-distance truck and rail corridors to other states	Develop a major truck/rail corridor in inland Florida to shift freight activity away from congested coastal regions and support planned intermodal hubs and facilities	Use new technologies to improve the efficiency of the supply chain	Create more options for visitors to easily move from airports and seaports to urban centers and major attractions	Total
Threats	**Risk Event**	**Sensitivity**						
	Hacking and cybersecurity threats to public and private transportation	3	2	1	1	1	1	**9**
	New technology causes investment to be prematurely obsolete	2	2	2	2	1	2	**11**
	Intensification of development in high hazard areas	1	1	2	2	3	2	**11**
	Aging population causes surge in demand for safe mobility options	3	3	3	3	3	3	**18**
	Wildfires disrupt major transportation routes and reduce visibility	3	2	2	1	3	2	**13**
	New technology systems perform unsafely or increase liability	3	1	1	1	1	1	**8**
	Failure to evacuate vulnerable populations due to evacuation routes in high hazard areas	2	2	3	3	3	3	**16**
	Arterial flooding disrupts major transportation routes and systems	3	2	2	2	2	1	**12**
							Total Scenario Robustness	***98***
							Robustness Percentage	***68%***

		Continue to deepen harbors, extend runways, and expand terminals to handle larger ships and planes	Improve road and rail connections to major seaports and airports	Improve long-distance truck and rail corridors to other states	Develop a major truck/rail corridor in inland Florida to shift freight activity away from congested coastal regions and support planned intermodal hubs and facilities	Use new technologies to improve the efficiency of the supply chain	Create more options for visitors to easily move from airports and seaports to urban centers and major attractions	Total
Opportunities	**Risk Event**	**Sensitivity**						
	Decrease in incidents caused by unsafe, distracted, and impaired driver and operator behavior	1	2	1	2	3	2	**11**
	AV offers safe mobility for aging population, teenagers, and users with limited mobility	1	2	2	2	1	2	**10**
	Enhanced real time data collection and reporting for safety, security incidents, and exposure	2	2	2	2	3	2	**13**
	Improved travel safety and decrease in intersection crashes	1	2	2	2	2	2	**11**
	Safer and more secure freight movement	2	2	2	2	3	1	**12**
	AV/CV /ICT facilitates real time communication, emergency response and recovery	2	2	2	2	3	2	**13**
	Improved safety and security of airspace due to technological advancements	2	2	1	1	2	2	**10**
	Blockchain strengthens digital security	1	2	2	2	3	2	**12**
	ICT improves transportation connectivity to military facilities	2	2	2	1	2	1	**10**
							Total Scenario Robustness	***102***
							Robustness Percentage	***63%***

Chapter 5
Planning Implications for Alternative futures

This chapter summarizes results of application of planning tools and frameworks to the different alternative futures outlined in the FTP Vision Element and policies and objectives outlined in the FTP Policy Element. The majority of work completed for this effort was done as part of a three-credit studio course at USF, entitled Adaptive Transportation Planning, which was held in the Fall of 2018. Under the direction of Evangeline Linkous, PhD, AICP, the 14-student class worked both in teams and individually to develop the content of this chapter. Students also prepared white papers and posters for presentation at the FTP Visioning Summit in 2019.

The goal of this effort was to determine how uncertainty leads to risks and how the consequences may impact the following alternative futures in the FTP Vision Element:

1) Return to Historic Growth
2) Rural Rediscovery
3) Global Trade Hub
4) Innovation Hub
5) Risks on the Horizon

With faculty guidance, students in the studio course were asked to apply the risk register tool discussed in Chapter 4 to the five alternative futures to understand levels of threats and opportunities presented by each future. Students also analyzed the construction and development of the FTP alternative futures using established scenario planning methodologies and revisited the alternative futures based on best practices involving the use of driving forces. Additionally, the class contributed original concepts to enhance planning for alternative futures in the FTP update.

Background

The 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. The FTP, which is updated every five years and was last updated in 2015, includes three major elements:

- The FTP Vision Element provides a longer-term view of major trends, uncertainties, opportunities, and desired outcomes shaping the future of Florida's transportation system during the next 50 years.
- The FTP Policy Element defines goals, objectives, and strategies for Florida's transportation future over the next 25 years. The Policy Element is the core of the FTP

and provides guidance to state, regional, and local transportation partners in making transportation decisions.

- The FTP Implementation Element defines the roles of state, regional, and local transportation partners in implementing the FTP, including specific short- and medium-term actions and performance measures.

The FTP Vision Element (FDOT 2015c) provides this summary overview of the alternative futures:

- ***Return to Historic Growth*.** High growth in population, visitors, and the economy, with similar development patterns and industry mix as today.
- ***Rural Rediscovery*.** Focus on rural areas and small towns, including traditional industries such as agriculture and eco-tourism, as well as newer sectors.
- ***Global Trade Hub*.** Significant expansion in global trade, tourism, and investment.
- ***Innovation Hub*.** Emphasis on technology and innovation, particularly in urban centers.
- ***Risks on the Horizon*.** Florida's future is at risk due to slowing population growth, economic uncertainties, or extreme weather events and climate trends.

A one-page description for each alternative future is also provided in the FTP Vision Element, with four descriptive elements for each:

- ***What If?* questions** – Each alternative future includes 3-4 questions that describe potential transformative changes in the economy, technology, environment, and/or socio-economic conditions that correspond to the specific alternative future.
- ***Could We*? questions** – Each alternative future includes 3-6 questions that describe decisions and opportunities presented by each future.
- **Hypothetical Resident Narrative** – Each alternative future includes a brief hypothetical statement that captures the voice and perspectives of a Florida resident, worker, or visitor in the alternative future.
- **Image/Graphic** – Each alternative future includes an image or graphic depicting the character of the alternative future.

Scenario Analysis Screening

To begin the scenario screening process, the class consulted the literature and elected to use the scenario analysis tool developed for the World Bank by Maack (2001) to focus the analysis. This highly cited, landmark report offers a simple but useful framework for structuring scenario analysis, a feature that was useful for organizing the class's work. This tool is shown in Table 17.

Table 17. Steps From Scenario Analysis: A Tool for Task Manangers

Constructing or Developing Scenarios	1. Define a focal issue or decision.	Scenarios are best suited to looking at the future through the lens of a specific issue, such as the likely outcome of a national election leading to a transfer of power or a currency devaluation. Without this grounding, there is a danger that they will be too general.
	2. Identify driving forces.	These are the social, economic, environmental, political, and technological factors that are most relevant to the focal issue. They should be prioritized by the scenario team according to their level of predictability and importance in affecting the desired outcome.
	3. Write scenario plots.	These are the stories that explain how driving forces interact and what effects they have on the operation or strategic direction being discussed.
	4. Flesh out scenarios.	Good scenarios combine a solid understanding of relevant present trends with a clear focus on the outcomes sought by decision-makers. They should incorporate lessons revealed by analysis of quantitative and qualitative data relevant to the assumptions underlying each scenario.
Integrating the Content of Scenarios into Decision-making	5. Look at implications.	After scenarios have been fully developed, decision-makers should study their implications for the outcomes being sought by the operation.
	6. Choose "leading indicators."	These indicators should help decision-makers monitor changes in the external environment as well as developments in the project.
	7. Disseminate scenarios	Once scenarios have been built and refined, they should be written in succinct, easy-to-read language and disseminated within implementing organizations and to the public.
	8. Integrate scenario outcomes in daily procedures.	Change the incentive system in affected agencies and areas to ensure concerted movement toward the strategic goals that have been formed on the basis of the scenarios. Use or modify existing systems to monitor progress toward operational goals as well as changes in the external environment.

Source: Maack, 2001

As shown in Table 17, scenario analysis should begin with the first four steps, which are collectively entitled *Constructing or Developing Scenarios*. The class applied these steps in the analysis of the FDOT FTP alternative futures. This review established the foundational understanding of each scenario.

Define a Focal Issue or Decision

The Maack guidance indicates that the first step in scenario planning exercises is to define a focal issue or decision. Although the FTP Vision Element describes the five alternative futures, it offers limited guidance as to how these futures should be used in transportation planning processes. It states that the five potential futures "help guide discussion about the state's

future transportation needs and opportunities" and "help understand and prepare for the range of possibilities facing Florida's transportation system—not to select a single preferred future" (FDOT, 2015c).

The FDOT FTP alternative futures are general, depicting changes that will impact the State of Florida as a whole. The *What If?* questions—which describe each future—encompass very broad themes. The *Could We?* questions get closer to transportation-specific policy decisions that may be considered given the conditions presented in the alternative future.

The Maack guidance suggests that the FDOT FTP scenarios may be too general and lack a focal issue or decision focus. Given the guidance that "scenarios are best suited to looking at the future through the lens of a specific issue" (Maack, 2001) FDOT might consider how to orient the alternative future toward specific decision-making applications, such as where infrastructure investments should be made or what type of investments should be prioritized. The Maack report provides an example from a New Jersey Department of Transportation scenario planning process. In that effort, "the decision focus was whether transportation investment should focus on sustaining existing infrastructure, expansion of highways, or the development of light rail" (Maack, 2001).

Identify Driving Forces

Once a decision-making focus is established, the next step is identification of driving or external forces. This step reviews the social, economic, environmental, political, and technological factors that pertain to the decision-making issue. Emphasized in Maack's work, this step is adapted from Wilson (1998). This step is summarized and illustrated in Table 18.

Table 18. SEEPT Framework for Identifying External Forces

Table 1. Illustration of the SEEPT (Social, Economic, Environmental, Political and Technological) Framework for Identifying External Forces

This is an illustrative SEEPT framework for a national-level scenario exercise. This chart can serve as a menu for scenario teams or as a stand-alone example of the sort of questions that can be posed in each of the SEEPT categories. The Social Indicators of Development, Country Political and Institutional Assessment information, United Nations Development Programme (UNDP) Human Development Indicators, and the World Development Indicators are useful sources of data for these domains.

Domain	Category	Examples
Social	Social factors	Education levels, social priorities, cultural and class tensions, land and water rights, differentiated membership in groups and associations, gender issues
	Demographic patterns	Age, family, household, and ethnic structures; regional and national migration patterns; wealth distribution, including regional and national poverty rates
Economic	Macroeconomic conditions	GNP, balance of trade, rate of inflation, exchange rate; current and future relations with international financial markets, current debt levels; governmental expenditures, deficits Changes in the economic structure of nation (dependence on single export, percentage of exports in finished goods), formation of new regional trading blocs
	Microeconomic conditions	Change in size, type and ownership of firms; formal and informal labor force structure by region; changes in economies of scale/structure of key industries
	Market forces	Spending patterns of consumers (urban/rural, national/regional), international demand for key exports Distribution and efficiency of rural and urban markets, impact of the informal sector, sources of competition (national, regional, international)
	Impacts of global economy and development	Volume of assistance from multilateral and bilateral agencies, conditions for assistance (policies, requirements)/harmonization Risk tolerance and conditions for entry and exit by international firms, stake in local economy by international firms
Environmental	Physical environment	Air/water/land pollution trends and locations, environmental quality issues (global warming)
	Natural resources	Energy prices and availability (likelihood/impact of an oil shock), raw materials (rate of depletion, ease of access), land use (farming methods, erosion levels), sustainability (strategic use of resources) regional distribution of natural resources
Political	Geopolitical	Trends in international relations; relationship with other nations in region (regional trading blocs, military alliances); levels of tension, conflict (regional, international); trade and protectionism
	National	Change in governmental development strategy and policy (privatization); changes in legislation (including regulation, creation of enabling environment); changes in structure and responsibility of ministries; changes in rules governing formation and functioning of parties; stability of government, likelihood of change/overthrow
Technological	Infrastructure	Level of technology in key industries, emerging technologies, capacity to manufacture technology for export
	Future directions	Basic research and technical education trends in nation; "digital divide" – computer and telecom infrastructure/trends; potential for the rapid diffusion of new technologies from abroad

Source: Adapted from Wilson 1987.

Source: Maack, 2001

Driving forces as defined by Maack included two categories:

- **External forces** – the social, economic, environmental and political forces in society that are relevant to the topic of the scenario discussion but outside the participants' control; and
- **Organizational forces** – the specific actions and general positions taken by actors (individuals, agencies, and organizations) that affect project success.

Maack indicates that driving forces are the "key foci" of scenario development. He emphasizes that complex analysis is not required, but that it is crucial to examine cause-and-effect relationships and the apparent direction of the forces today—which allows for extrapolation. The key takeaway is that scenario development must be grounded in consideration of directional forces from which trends—however uncertain—can be projected. The use of driving forces is essential for scenario construction to be useful for planning purposes.

To continue the example from the New Jersey Department of Transportation scenario planning process that centered on transportation investment decisions, Maack provides an illustration of how driving forces are used to develop scenarios, shown in Figure 48.

Box 4. Scenario Drivers in the New Jersey Department of Transportation

The decision focus was whether transportation investment should focus on sustaining existing infrastructure, expansion of highways, or the development of light rail. The group agreed on the three most important driving forces for the scenarios:

1. *Rate of regional and national economic growth.* The team looked at high, medium, and low levels of GNP growth and the rise or fall of the two major urban areas that affected the state. They studied the nature of growth (technological or industrial) and the effect of the economy on private investment in transportation and public sector revenue.
2. *Values and attitudes of citizens.* Citizens were modeled as inwardly oriented and individualistic, or outwardly oriented and communal. The inward-looking citizen had a continuing love of cars and single-family homes, a strong distrust of government, and was rent-seeking. The outwardly oriented citizen was more urban and environmentally conscious, wanted to revitalize cities, and trusted government more.
3. *Government leadership.* The government was modeled as oriented to the short term and crisis management, or oriented to the long term and able to stay with a stable plan.

Each of the scenarios looked at the relationships among the three driving forces and their effects on factors such as the environment, investment, education (what is the workforce doing?), and traffic flows. Scenario logics were consistent. A low-growth scenario had a greater split between rich and poor, an emphasis on safety, and a government that focused on short-term solutions due to constrained resources. In another scenario, technology drove strong national and regional growth; immigrants were middle-class; and convenient transportation was emphasized in more densely developed urban areas.

Figure 48. Scenario drivers used by NJDOT

Source: Maack, 2001

The driving forces underlying the FDOT FTP alternative futures are not identified in the Vision Element, which presents challenges for assessing the related planning implications. For example, as already discussed, it is not clear what forces would lead to a *Rural Rediscovery* future. Given this gap in the construction and development of the FDOT FTP alternative futures, we consider how external forces could be constructed for these futures.

Although understanding directional forces is key to scenario planning, Maack acknowledges that addressing unpredictable and uncertain futures is central to the process. Maack proposes creation of a matrix to address impact and uncertainty, as shown in Table 19.

Table 19. Impact and Uncertainty Matrix

Degree of uncertainty			
Low	**Medium**	**High**	
Critical planning issues Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in *all* scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discon-tinuities also should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots and trigger exit strategies.	**High**
Important planning issues Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues that are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.	**Med**
Monitorable issues Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.	**Low**

Level of impact

Source: Maack, 2001

Write Scenario Plots

Once the driving forces are identified, scenario plots are created to explain how driving forces interact and what effects they have on the decision-making focus. An example of a scenario plot for revisited versions of FDOT's FTP alternative futures is provided toward the end of this section (Table 26 & Figure 49).

Flesh Out Scenarios

The next step for scenario initiatives is the fleshing out of scenarios. Maack indicates that this should "incorporate lessons revealed by analysis of quantitative and qualitative data relevant to the assumptions underlying each scenario." The FDOT FTP report illustrates what the scenarios will look like but does not offer guiding information about the underlying causes for the fleshed out scenarios. Students conducted research related to each alternative future to establish additional contextual information for understanding its potential implications.

Integrating the Content of Scenarios into Decision-Making

The latter half of the Maack framework incorporates the following steps for integrating scenario content into the decision-making process.

Look at Implications

Identifying the implications for outcomes sought is the final step in scenario construction and development. Decisions for how the scenarios can be used—such as whether the scenarios will be used to formulate strategies or build a shared vision—are made at this stage. This is a step where project assessment or selection could be integrated.

Choose Leading Indicators

Indicators help decision-makers monitor and react to changes in the external environment or developments in the project.

Disseminate Scenarios

In this step, FDOT must address how to refine scenarios into easy-to-read language for use by implementing organizations such as District offices and the public.

Integrate Scenario Outcomes in Daily Procedures

This final step involves changing the incentive system in an affected agency to move toward the goals formed on the basis of the scenario analysis.

Application of SEEPT to FDOT FTP Alternative futures

The SEEPT framework identified by Maack emphasizes a number of critical factors as integral to scenario planning. These include defining a focal issue and identifying driving forces—two components that provide directional information in the otherwise uncertain and unpredictable exercise of planning for uncertain futures.

The preceding discussion shows the importance of using a decision-making focus and driving forces as the foundations on which alternative futures are based. This allows for logical, trending outcomes to be predicted. The FDOT FTP alternative futures are relatively static visions that do not clearly correspond to underlying causes. FDOT alternative futures do not provide enough background on why static visions of say, *Rural Rediscovery* for example, might materialize. Without identifying underlying driving forces, it is difficult to understand the transportation planning outcomes that will be impacted.

Identfiying External Forces

Given the focus of analyzing the existing FDOT FTP alternative futures, the decision was made to “work backwards” from these established futures to consider the external forces that might underlie each future. To this end and in order to provide a planning tool for use by FDOT, a table of external forces was developed.

The FDOT FTP content focuses on changes within the state of Florida and does not describe how larger, external forces will influence outcomes. For many of the forces, it was difficult to interpret how the state-based futures would interact with global and national forces. Instead of attempting to add or overlay dynamics not clearly addressed in the Vision Element, the analysis worked within the parameters of the given scenario descriptions.

The analysis presented two particular challenges. First, it was unclear how to address the environmental factors. It can be assumed that hurricanes will strike in all scenarios, but one must also consider differentiated levels of sea level rise, with lower levels corresponding to the Innovation Hub and Global Trade Hub futures, where technological innovation is high. The assumption can be made that these technological innovations might assist in combating climate change and sea level rise. Second, the mix of decline and growth presented in the *Risks on the Horizon* scenario presented challenges and presented difficulties when trying to posit external forces that rationalized this future. Based on this issue, ways to reframe this future are discussed in a later section.

Values included in Figure 15 were determined using a number of factors. For Florida-specific data − such as the annual population growth rate, job growth rate, and annual federal transportation funding – current data were used, and hypotheses were developed about how existing conditions would vary under each future. For example, Florida's 2017-2018 population growth rate was 1.5%, which is a strong rate of growth that was assumed would be maintained or enhanced in growth-oriented futures such as *Global Trade Hub* and *Innovation Hub*. For more global trends, predictions from the San Francisco Bay Area Metropolitan Transportation Commission (MTC) report were extrapolated to identify how they applied to the FDOT FTP futures. For example, MTC assumes an e-commerce market share of 50% in a scenario that features innovative technology development and population growth, so we used this measure for *Innovation Hub*.

Table 20. Proposed External Factors Input Model for FDOT FTP Alternative futures

External Forces			Return to Historic Growth	Rural Rediscovery	Innovation Hub	Global Trade Hub	Risks on the Horizon
Environmental	1	Sea Level Rise	3 feet	3 feet	1 foot	2 foot	3 feet
	2	Natural Disasters	Cat 5 Hurricane	Cat 5 Hurricane	Cat 5 Hurricane	Cat 5 Hurricane	Cat 5 Hurricane
Economic	3	Florida Population Annual Growth Rate	+2.0%	+1.0%	+2.5%	+1.5%	+0%
	4	Florida Jobs Annual Growth Rate	+2.0%	+1.0%	+2.5%	+1.5%	+0%
Land Use	5	Housing Preferences	Greater preference for dispersed housing	Greater preference for dispersed housing	Greater preference for urban housing	Greater preference for urban housing	Greater preference for urban housing
	6	Telecommute Share	10%	15%	30%	20%	5%
	7	E-Commerce Market Share	20%	25%	50%	35%	15%
Transportation	8	Transportation Technologies	Cars, autonomous buses	Cars, autonomous buses	High speed rail, autonomous rail and buses, freight aerial drones, lower-cost helicopter transport	High speed rail, autonomous rail and buses, freight aerial drones, lower-cost helicopter transport	*Unclear*
	9	Autonomous Vehicle Market Share	20%	30%	80%	65%	*Unclear*
	10	Sharing Preferences	Similar preference to today	Similar preference to today	Greater preference	Greater preference	*Unclear*
	12	Annual Federal Transportation Funding	$5.5 billion	$5.5 billion	$8 billion	$6.5 billion	$8 billion

Implications for the FDOT FTP Alternative Futures

The input table begins to suggest the implications for each alternative future. However, the decision-making focus would require further refinement for it to be fully useful. For example, if a decision-making question centered on how much FDOT should invest in infrastructure that supports AV, the *Innovation Hub* and *Global Trade Hub* are futures where this becomes critical.

As part of the process of looking at the implications of the FDOT FTP alternative futures (Maack methodology step 5), the class also conducted a separate screening analysis using the risk register tool concept and the conceptual "alternative future robustness" screening methodology identified in Chapter 4.

A critical takeaway from the findings is that technology and funding have the potential to present tremendous opportunity in some alternative futures; however, without technology and funding solutions, these same alternative futures pose threats. The application of the tool indicates that *Could We?* statements yield optimistic perspectives on the uncertainty presented by some alternative futures, especially when these futures are highly dependent on new technology and funding resources. This finding presents two important implications.

- First, it suggests potential alternative approaches to the alternative future screening tool. Although the tool as designed and applied provided important insights when used to contemplate long-range change, a project planning application could more readily incorporate real-time feedback and other data inputs, benchmarks, and indicators of actual, measurable (instead of anticipated) changes or advancements—such as technology adoption—that present opportunities or threats in a given alternative future.
- Second, the analysis brings attention to the critical role uncertainty and change related to technology and funding will play in future transportation planning processes.

Of all the alternative future/goal combinations, the *Innovation Hub* for Quality Places goal is the most compelling in terms of minimal threats and high opportunities. The *Innovation Hub* alternative future also scores very high for total alternative future robustness for safety (74%) and choices (72%) goals, and generally does well across all other measures. These findings suggest that the *Innovation Hub* alternative future is an alternative future that offers FDOT a desirable platform for future transportation planning—whether the agency works proactively to shape transportation planning to support this future or if the agency must be responsive to trends indicating this future for Florida.

On the contrary, the alternative future/goal combination of *Rural Rediscovery* for the Infrastructure goal ranks lowest for total alternative future robustness. Total alternative future robustness for all but one of the *Rural Rediscovery* goals was below 70%. Likewise, threats across most goals for *Rural Rediscovery* are low, suggesting an alternative future that will present high susceptibility to threats and therefore significant challenges for future transportation planning in Florida. Overall, *Rural Rediscovery* does not appear to be a future

with desirable planning implications. However, the *Rural Rediscovery* alternative future is not all problematic, and scores well when just opportunity robustness is examined for some goals.

Looking Forward: Choose Leading Indicators

The class next identified indicators for each alternative future that could be used to monitor whether the State is headed in a particular direction. This corresponds to the Maack model step 6. The intention here is to show a general trend indicated by a set of factors. Not all indicators and measures must be observed to suggest progress toward a future. For this reason, directional measures are used for most indicators, especially where specific to a future. For example, number of farms is expected to increase for *Rural Rediscovery*. For measures that overlap more than one future, a range is generally provided. For example, population growth in *Return to Historic Growth* is anticipated to be close to current levels of 1.25%-2%, while *Innovation Hub* anticipates increased growth, with a population growth measure of 2%+.

Indicators of Return to Historic Growth Alternative future

The following indicators could be tracked to assess whether Florida is headed in the direction of this alternative future (Table 21).

Table 21. Indicators of *Return to Historic Growth* Alternative future

Indicator	Measure
Population, annual growth rate	1.25-2%
Per-mile vehicle operating cost	$0.10-$0.30 per mile
Annual increase in vehicle miles traveled	0.5-0.10%
Average daily vehicle per lane mile on Florida State Highway system	increasing annually
Acres of farmland lost annually	35,000 acres or more
Per capita land consumption	increasing annually
Percent of Florida jobs associated with agriculture	increasing annually
Percent of Florida jobs associated with construction	increasing annually
Percent of Florida jobs associated with tourism	increasing annually

Indicators of Rural Rediscovery Alternative future

The following indicators could be tracked to assess whether Florida is headed in the direction of this alternative future (Table 22).

Table 22. Indicators of *Rural Rediscovery* Alternative future

Indicator	Measure
Population, annual growth rate – rural areas	2%+
Population, annual growth rate – small towns	2%+
Percent of Florida jobs associated with agriculture	increasing annually
Market value of agricultural products sold	Increasing annually
Number of farms	Increasing annually
Land in farms (acres)	increasing annually
Miles added to Florida trail system	Increasing annually
Number of visitors to State and National Parks in Florida	increasing annually

Indicators of Global Trade Hub Alternative future

The following indicators could be tracked to assess whether Florida is headed in the direction of this alternative future (Table 23).

Table 23. Indicators of *Global Trade Hub* Alternative future

Indicator	Measure
Population, annual growth rate	2%+
Florida's percent share of U.S. international trade	Over 4%
Percentage of national enplanements	Over 10%
Market share amongst states for air cargo/tonnage	increasing
Percent of U.S. cruise embarkations	Over 60%
Number of annual overseas visitors to Florida	increasing
Dollar value of goods that flow through Florida ports and airports	increasing
Number of jobs generated by Florida ports and airports	increasing
Percent of Florida jobs associated with manufacturing and engineering	increasing
Number of multinational companies headquartered in Florida	increasing
Dollars invested in Florida transportation infrastructure	increasing

Indicators of Innovation Hub Alternative future

The following indicators could be tracked to assess whether Florida is headed in the direction of this alternative future (Table 24).

Table 24. Indicators of *Innovation Hub* Alternative future

Indicator	Measure
Population, annual growth rate	2%+
Florida's Gross Domestic Product as percentage of national GDP	6%+
Number of multinational companies headquartered in Florida	increasing
Percent of Florida jobs associated with manufacturing, engineering, and construction	increasing
Percent of Florida jobs associated with service industries	increasing
Number of annual overseas visitors to Florida	increasing
Proportion of MSA residents living downtown	increasing
Percent automated vehicle market share	increasing
Percent transit as a share of commuting	Increasing
Percent bike/ped as a share of commuting	increasing
Dollars invested in Florida transportation infrastructure	increasing

Indicators of Risks on the Horizon Alternative future

Identifying indicators for *Risks on the Horizon* (Table 25) is problematic because the alternative future contains processes of decline and growth. It should be noted that a growth scenario would encompass the kinds of indicators provided for *Innovation Hub* and *Global Trade Hub*. These indicators are provided on the preceding pages.

Since indicators of decline are not associated with any of the other alternative futures, they are the focus in the table below. The following indicators could be tracked to assess whether Florida is headed in the direction of decline portrayed in this alternative future. Natural disasters and climate-related change are excluded because these are likely to occur in any future.

Table 25. Indicators of *Risks on the Horizon* Alternative future (Decline)

Indicator	Measure
Population, annual growth rate	Less than 1.25%
Unemployment	Increasing
Florida's Gross Domestic Product as percentage of national GDP	Less than 5%
Number of annual domestic and overseas visitors to Florida	decreasing

Alternative futures Revisited

The Maack methodology indicates that scenarios *must be built* on identification of a decision focus and the external forces from which forecasts can be made. A pathway for consideration is to rethink the alternative futures with more rigorous use of a decision-making focus and external forces. This strategy aligns with best practices, but represents a departure from FDOT planning currently in place. In light of these factors, this section explores additional tools to understand risk and uncertainty.

A crucial finding from our analysis in previous sections is that the alternative futures as presented in the FDOT FTP are not directly constructed based on specified external forces. This presents significant constraints for understanding the planning implications of the alternative futures, since project trends, identifying benchmarks, and otherwise monitoring and responding to the futures cannot be done in a way that connects to data. The development of alternative futures that flow out of an analysis of external forces would allow FDOT an opportunity to use alternative futures that correspond to underlying causes and can be better forecasted.

Decision Focus

Following Maack, the decision focus is first considered, with a resolution to "concentrate on the goals sought by the development intervention rather than on the specific process that will be used to reach these goals." Here, this step begins with the seven goals of the FDOT FTP:

1) Safety and security for residents, visitors, and businesses
2) Agile, resilient, and quality infrastructure
3) Efficient and reliable mobility for people and freight
4) More transportation choices for people and freight
5) Transportation solutions that support Florida's global economic competitiveness
6) Transportation solutions that support quality places to live, learn, work, and play
7) Transportation solutions that support Florida's environment and conserve energy

The MTC uses their guiding principles to focus the Horizon planning effort, and intends to use the guiding principles to evaluate projects by flagging projects that fail to support one or more of the guiding principles. One option, then, is for FDOT to use the FDOT FTP goals in a similar way. Scenarios should be developed in response to these desired goals—not to portray a static future.

Although the FDOT FTP goals present a helpful starting point for orienting the focus, use of seven criteria is cumbersome. Also, there are tensions between goals—for example, environmental and economic goals may not always go hand in hand. Therefore, a second option is to pursue clarification about the decision-making focus.

External Forces

Risks on the Horizon

The *Risks on the Horizon* alternative future is problematic to understand, define, or use from an external forces perspective. It includes external forces of serious economic and population decline, as well as natural disasters. Collectively, these external forces describe decline. At the same time, it anticipates external forces of major economic investment and technological innovation to adapt infrastructure and reenergize a stalled economy—which describes growth. As previously discussed, this alternative future includes a problematic mix of highly pessimistic and highly optimistic hypothetical situations that make it difficult to use for planning purposes. Should planners using this alternative future use it during the disaster and decline stage, or the investment and rebirth stage? Since these stages present radically different decision-making situations, this alternative future needs to be unpacked to separate the two outcomes.

Decline in this alternative future comes from natural disasters and stagnant or declining economic and population growth. Since natural disasters can be part of any future and Florida includes many features that make it particularly vulnerable to disaster, including sea level rise and hurricanes, this must be excluded from any particular alternative future and should instead be addressed through separate hazard mitigation and disaster response planning processes.

That leaves economic and population decline, which are not included in any of the other alternative futures. It also leaves economic investment and technology solutions, which are external forces already linked to the *Innovation Hub* and *Global Trade Hub* alternative future. Therefore, the Risks on the Horizon alternative future could be reduced to one of decline from external forces. This creates clarity about the circumstances a planner should respond to under this future. However, following Maack, the decision was made to use scenarios to look to desired outcomes based on trending forces. Most data indicate continued growth for Florida. Although planning for decline is a legitimate planning exercise, the decision was made not to pursue this alternative future any further for these reasons.

The Four Non-Risk Based Alternative futures

The four non-risk based alternative futures align with external forces in a fairly straightforward way. Analyzing the alternative futures from the perspective of external forces yields the insight that they may be reduced to two general groups.

Return to Historic Growth and *Rural Rediscovery* are more conservative visions that do not assume dramatic changes in technology, funding, and infrastructure development. These futures describe continued trends of moderate-to-high population and economic growth that is deconcentrated spatially.

Innovation Hub and *Global Trade Hub* describe more robust growth alternative futures accompanied by enhanced funding for infrastructure improvements and urban-centric growth. These are more radical visions that assume high levels of change related to the economy and technology.

The alternative futures, then, generally predict two different overall growth paths: 1) one with high population and economic growth based largely on transformative leaps forward in technology (this general future prospect is referred to as *Transformative Growth*), and 2) a second that assumes more moderate growth where the economy and technology continue "on trend" growth, but without transformative shifts (referred to as *Trend Growth*).

Organizational Forces

Looking to Maack, organizational forces are also considered. These are the institutional actions that affect outcomes. Based on a scan of the literature (primarily FDOT FTP, Horizon MTC, and Maack), the class identified two poles of primary organizational forces that impact transportation futures. These are:

- *Sustainability and Equity* – government elects to support—through both policy and funding—a framework for equity and sustainability that is oriented primarily around multimodal approaches to transportation (Sustainability and Equity); or
- *Economic Efficiency* – government focuses on an economic efficiency transportation policy framework that focuses more on re-engineering regional highway infrastructure, modernizing port and freight facilities, and airport modernization.

Depending on the institutional goals and forces relevant to FDOT, a different set of organizational forces could be identified and applied. For example, as described in the Maack report, the New Jersey Department of Transportation used *Inward-Looking Citizens* to describe an institutional context focused on highway transportation investment, and *Outward-Looking Citizens* to describe a focus on public transportation and sustainable technologies. As another alternative, we suggest *Regional Movement* and *Local Accessibility* as other potential poles that could be used for describing the institutional context for policy decisions in transportation planning. The purpose is to describe the forces that guide the policy agenda for FDOT as it responds to external forces.

Putting it all Together: Revisited Futures Matrix

Looking at the linkages and directional flow of the external and organizational forces, four potential futures emerge as shown in Table 26, below:

Table 26. Alternative futures Revisited: Scenario Plot of External and Organizational Forces

Revisited Alternative future	**External Forces**	**Organizational Forces: Policy Framework/Funding**
Green Innovation	Transformative Growth	Sustainability and Equity
Green but Lean	Trend Growth	Sustainability and Equity
Commerce and Trade	Transformative Growth	Economic Efficiency
Status Quo	Trend Growth	Economic Efficiency

Additionally, a revisited futures matrix was developed (Figure 49) that further fleshes out each of the revisited alternative futures.

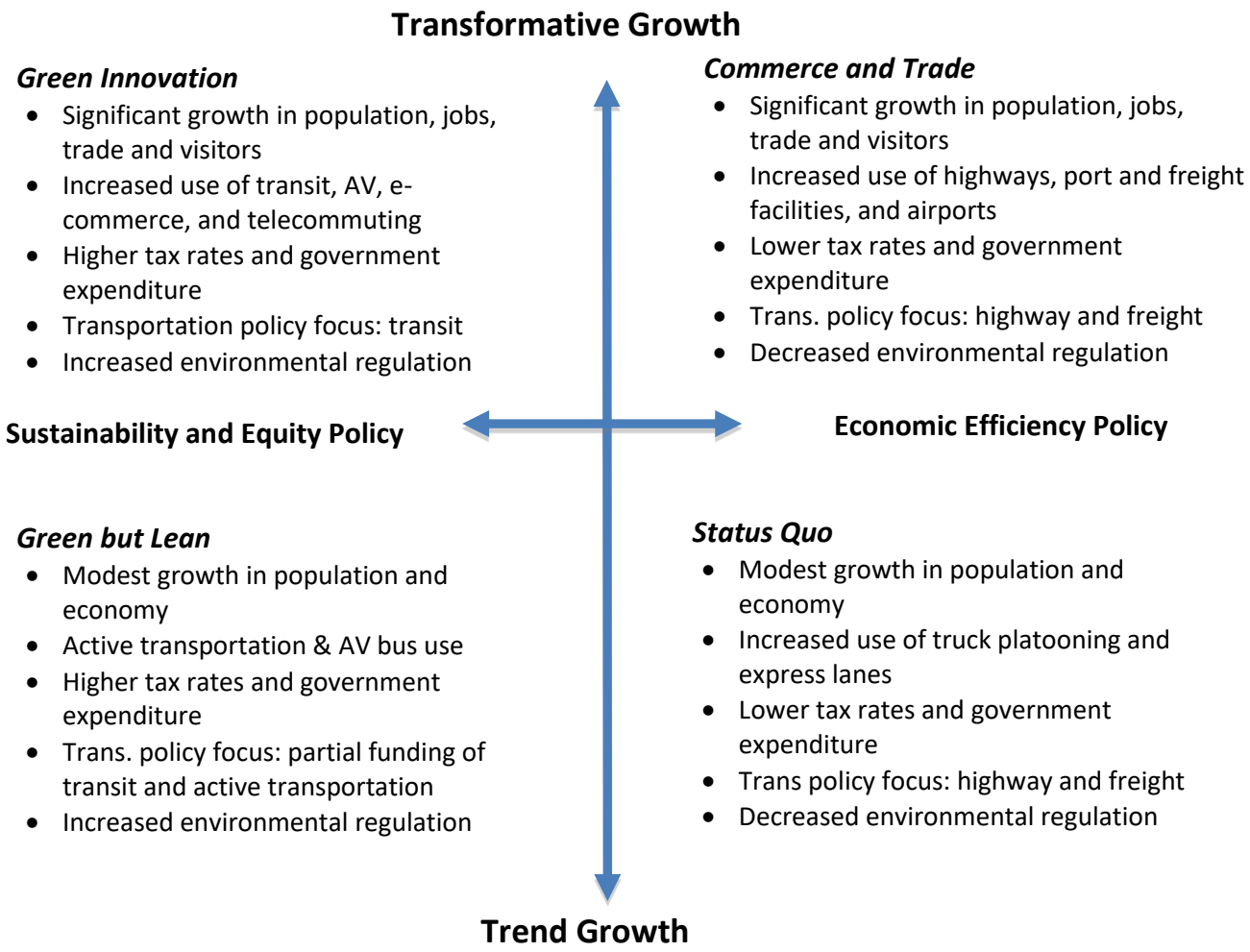


Figure 49. Alternative futures revisited: scenario matrix

Framework Selection

Given the alternative future matrix, an input model of external forces to further flesh out the futures can be constructed. To do so, the external force framework categories used by SEEPT and MTC were compared, shading in gray the overlapping categories used in both approaches.

The SEEPT model considers the following external forces:

- Social
- Economic
- Environmental
- Political
- Technological

The MTC model considers the following external forces:

- Environmental

- Political
- Economic
- Land Use
- Transportation

The SEEPT approach was selected for two reasons. First, the risk register analysis indicated the tremendous importance of technology and funding. Since funding is covered in the political category, it is imperative to account for technology—which the SEEPT model does. The direct inclusion of the social category was preferred because demographic changes (especially related to the aging of the population) loom large as a critical issue for Florida, and also because the social aspects of mobility and transportation are increasingly recognized as a critical issue for transportation agencies. It is concluded that land use and transportation are largely influenced by the other categories, such as social, technological, and economic forces.

Selection of external forces (Table 27) was informed by examining factors contributing to risk and uncertainty identified in Chapter 2, considering the external forces that are suggested by FDOT FTP alternative futures, and reviewing external factors present in the Horizon MTC futures.

Following Maack, the larger set of forces most relevant to policy decisions become the emphasis for the decision focus. The set of external forces is limited to those most critical for the future of transportation planning in Florida based on this review.

A future study could continue to develop forecasts based on this input model, similar to the Horizon MTC study. These forecasts could then be analyzed against FDOT FTP goals to evaluate implications of the futures.

Table 27. Input Model for External Factors, Alternative futures Revisited

External Forces		Green Innovation	Commerce and Trade	Green but Lean	Status Quo
Social	Population growth rate	2%+	2%+	1.25-2%	1.25-2%
	Age	Increasing share age 55 & under	Increasing share age 55 & under	Increasing share age 55+	Increasing share age 55+
	Wealth gap	Decreasing	Increasing	Decreasing	Increasing
Economic	Florida's GDP as percent of national GDP	8%+	8%+	4-7%	4-7%
	Annual visitors to state, annual growth rate	Over 3.5%	2.5-3.5%	Over 3.5%	2.5-3.5%
Environmental	Tax structure	Carbon taxes introduced	Similar to today	Carbon taxes introduced	Similar to today
	Environmental regulation	Increased	Decreased	Increased	Decreased
	Housing/land use preferences	Urban concentration	Decentralized	Urban concentration	Decentralized
	Environmental quality	Enhanced	Declining	Enhanced	Declining
Political	Annual federal transportation funding	Increased	Similar to today	Increased	Similar to today
	State tax rates	Increased	Similar to today	Increased	Similar to today
	State spending levels	Increased	Similar to today	Increased	Similar to today
	Transportation policy focus	Transit, active transportation	Highway and freight improvements	Partial funding of transit and active transportation	Partial funding of highway and freight improvements
Technological	Electric vehicle market share	75%	50%	50%	25%
	Autonomous vehicle market share	75%	50%	50%	25%
	Per-mile vehicle operating cost	$0.35 per mile	$0.15 per mile	$0.50 per mile	$0.20 per mile

Using the Alternative futures in Planning

The revisited alternative futures are more closely linked to external forces, as well as organizational and decision-making forces. Potential next steps might involve further fleshing out the alternative futures, potentially using a graphical approach, such as that used by MTC. It would also be helpful to create further clarity about the potential policy and funding decisions that might vary between *Sustainability and Equity* and *Economic Efficiency*. Finally, another step could be to develop a decision-making tool that links the alternative futures to FDOT FTP goal areas for use in project planning or performance assessment.

Chapter 6
Project-Level Transportation Planning

This chapter examines the project-level planning process, as detailed in FDOT guidance for transportation planning studies. The analysis is then used to develop recommendations for further integrating consideration of risk and uncertainty into project-level transportation planning. These recommendations incorporate concepts that can strengthen planning practices already used by FDOT and other state transportation agencies. The project team also used research findings from the literature, as documented in previous chapters, to develop a Project-Level Planning Risk Assessment Prototype that can be integrated into existing planning processes

Project-Level Risk

Project risks are specific to individual projects and affect the successful accomplishment of project objectives (FHWA, 2012c). These risks relate to cost, scheduling, and safety, along with various other internal and external forces. Two levels of project risk are identified in the literature:

- Individual risks, or lower level risks, are "specific events or conditions that might affect project objectives. An individual risk may positively or negatively affect one or more of the project objectives, elements, or tasks" (Project Management Institute, 2009, 2013 as cited by Hillson, 2012).
- Overall project risk, or higher-level risk, is "the effect of uncertainty on the project as a whole. Overall project risk is more than the sum of individual risks on a project, since it applies to the whole project rather than individual elements or tasks [and since it includes all sources of project uncertainty]" (Association for Project Management, 2004, 2012 as cited by Hillson, 2012)

These levels are generalized as the risks ***in*** the project and the risk ***of*** the project. Wider influences in the environment and context of the project cause overall project risk, therefore the following frameworks are suggested by Hillson (2014) when identifying overall project risk:

- PESTLE – Political, Economic, Social, Technological, Legal, Environmental
- PESTLIED – Political, Economic, Social, Technological, Legal, International (or Informational), Environmental, Demographic
- STEEPLE – Social, Technological, Economic, Environmental, Political, Legal, Ethics
- InSPECT – Innovation, Social, Political, Economic, Communications, Technology
- SPECTRUM – Socio-cultural, Political, Economic, Competitive, Technology, Regulatory/legal, Uncertainty/risk, Market
- TECOP – Technical, Environmental, Commercial, Operational, Political
- VUCA – Volatility, Uncertainty, Complexity, Ambiguity

The FDOT Planning Process

This section is a review of the planning process for FDOT Transportation Planning Studies. The subsequent section will provide a model framework for addressing risk in project-level transportation planning including a suggested application of tools.

The FDOT process for transportation planning studies (Figure 50) is outlined below:

1) A preliminary needs assessment
2) A planning study
    - Existing conditions – information collected at this stage helps to identify existing conditions that do not meet or support the goals and objectives of the study and are inconsistent with the future vision.
    - Future conditions - information collected at this stage identify future trends and conditions are not expected to meet or support the goals and objectives of the study and are inconsistent with the future vision.
    - Issues and opportunities - major problems and opportunities that could be addressed by transportation investments, management and operational strategies, and policy changes in the study area.
    - Potential solutions - formulate concepts and strategies to address issues and opportunities identified in previous activities.
    - Alternatives for advancement - identify which project alternative(s) can be advanced in the near term given available funding and support, what long-term strategies can build on these initial investments and policy changes and support the long term vision for the study area, and what intermediate strategies can help advance the study area toward its goals when funding is available and other conditions are in place.
    - An action plan – document the knowledge that has been developed in the planning process to date so that this information can be used to improve project design and implementation.
3) PD&E
4) Design
5) Construction

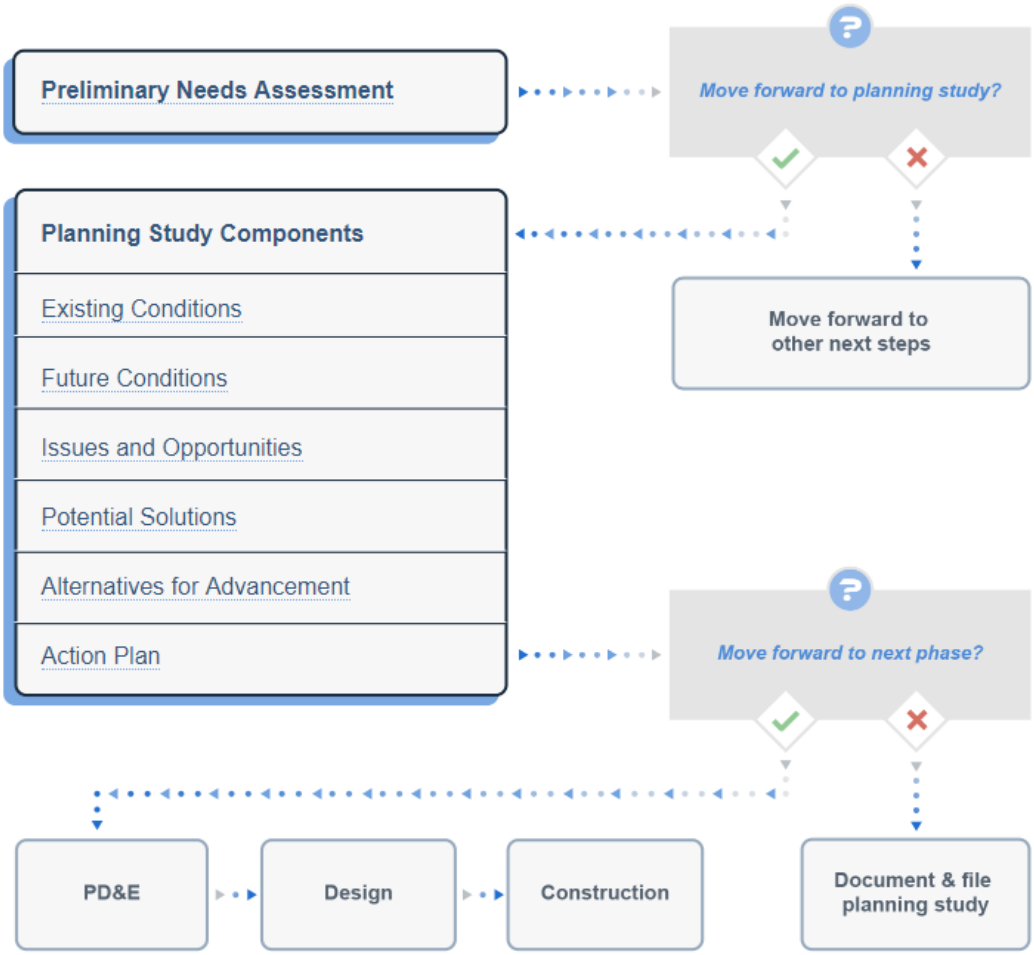


Figure 50. FDOT transportation planning process

Source: FDOT

Supplementary to the process outlined in this section, the *FDOT Planning Processes: Components of Plans and Studies Working Draft (5/21/2018)* identifies the framework and activities for each of the planning process components. The document begins by listing the major actives that take place during transportation planning, followed by a matrix of potential planning challenges and starting points. The remainder of the document identifies key decisions, illustrative products, and examples of activities undertaken and possible next steps for each planning activity.

Guidance on Uncertainty and Risk

Uncertainty and risk are currently integrated into the decision-making process at key points during various planning activities. Some examples of planning activities and questions to prompt key decisions to be made and documented include:

- Pre-study scoping
    - What risks and challenges might we face along the way?

- Establish consistency with existing plans and visions
    - What are potential sources of uncertainty in the future over the established planning horizon? Do existing plans and visions express desired future outcomes or suggest a range of plausible and acceptable futures?
- Project future conditions
    - What are potential risks and future outcomes?
- Identify performance gaps and opportunities
    - What are the major problems and opportunities that could be addressed by transportation investments, management and operational strategies, and policy changes in the study area?
- Evaluate and compare potential solutions
    - Which alternatives or groups of alternatives should be advanced to project development in order to best meet the goals and objectives of the study area?
    - What are immediate opportunities for making improvements to transportation facilities and services with low cost and little risk?
    - What alternatives require further study or development before they can be advanced?

The existing process for transportation planning studies presents opportunities to evaluate future risk and uncertainty at the project-level. A limitation of the process is its sequential and linear design, which provides diminishing opportunities to reevaluate the project as the process advances. An iterative framework, such as those found in adaptive planning processes, can provide the needed adaptability. The following chapter explores a conceptual framework for project-level risk assessment that can be integrated into existing FDOT planning processes.

Project-Level Risk Management Application and Framework

The project team identified possible applications for different approaches to risk management that can be integrated into existing FDOT planning processes. Proposed tools are not meant to replace existing tools and strategies, but instead, enhance those already in use.

Using concepts of Adaptive Decision-Making (ADM), the Adaptation Decision-Making Assessment Process (ADAP), and Project Risk Management (PRM), the project team developed a framework for a more adaptive project-level planning process. The ADM framework was selected because of its iterative design and its ability to address evolving conditions. The ADAP was selected because of its ability to assess sensitivity to future uncertainty and to more directly consider those uncertainties in project design. PRM was selected because it provides a process to identify individual risk events and measure overall risk exposure.

Methodology

The process to integrate adaptive decision-making strategies into project-level planning processes is outlined below:

1) Identify areas in current FDOT planning processes where risk identification and/or management are incorporated into the decision-making process and where adaptive decision-making strategies are identified. (This review relied on guidance in *FDOT Planning Processes: Components of Plans and Studies Working Draft (5/21/2018)*.) Evaluate plans and studies to determine where alternative futures/scenarios are identified and how the information is used to inform project-level risk and uncertainty.
2) Review and evaluate ADM, ADAP, and PRM literature and frameworks to identify how these processes might be applied in a project-planning context. Explore strategies suitable to address a wide range of risks and uncertainties that have the potential to impact Florida's transportation system.
3) Determine how the ADM, ADAP, and PRM frameworks might be modified and integrated into the FDOT planning process to enhance project-level transportation planning processes.
4) Develop a prototype for ADM, ADAP, and PRM in project-level transportation planning processes that considers scenarios. This step also relied on findings from the scenario analysis conducted in Chapter 5.

Project-Level Planning Risk Assessment Prototype

Using the methodology described in the previous section, a conceptual framework for project-level planning risk assessment was developed. The steps are shown in Figure 51 and explained below.

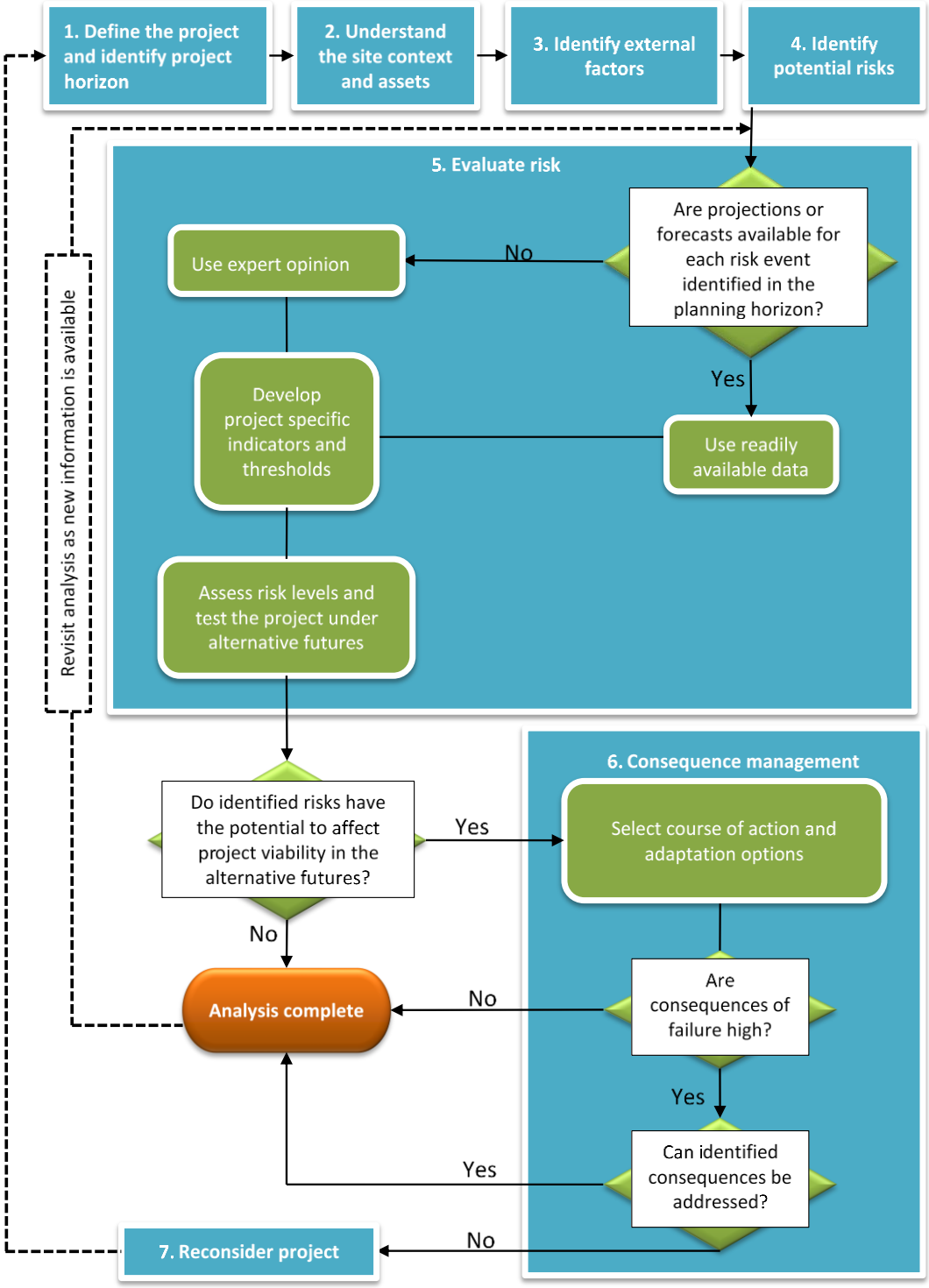


Figure 51. Project level planning risk assessment process

1. Define the project and identify project horizon
   Identify project type, purpose, and the intended outcomes of the project. Results from this step should be specific and detailed and should include goals, objectives, performance measures, etc.

   The project horizon should identify the proposed project completion date. Additional information can include average service life of assets (pavement, bridges, culverts, etc.), proposed maintenance schedule, and anticipated immediate and long-term impacts of the project.

2. Understand study area context and assets affected
   Activities to collect study area data and define study are context include a review of existing plans and studies, an existing conditions analysis, community meetings to identify community needs and evaluate potential consequences on impacted communities, etc. Review existing asset inventories to identify project-related assets and assets that may be impacted by the project. If an asset inventory does not exist, one can be developed. Categorize assets by function, location, or any combination of groupings determined appropriate by the agency. Table 28 shows an example of how FDOT's assets were categorized in Chapter 3.

Table 28. Example Assets by Category

Highway Assets	Structure Assets	Safety Assets	Multimodal Assets	Vehicle Assets	Technological Assets	Real Estate Assets
Pavement Interchanges (including ramps) and intersections Corridors	Bridges and Tunnels Culverts Mechanically Stabilized Earth (MSE) retaining walls Ditches Catch basins Under/edge drains	Barriers, (e.g., guard rails) Signals Signs Lighting systems (e.g., fixtures, poles, controllers) Pavement markings (e.g., raised markers stripping, rumble strips stripes, sidewalks, ADA assets)	Railway yards and stations Ports Bikeway, sidewalk, and trails Airports Intermodal Facilities Weighing stations	Transit fleet Incident Response Vehicles (IRV), (e.g., FDOT Road Ranger fleet)	Traffic management centers Intelligent Transportation Systems (ITS), (e.g., variable message signs, toll-by-plate, signal timing)	Rights-of-way Vacant parcels and government-owned lands Rest areas and welcome centers

3. Identify external factors

   Identify and document external factors that could affect the project using one of the following frameworks to identify and group factors:

   - SEEPT – Social, Economic, Environmental, Political, Technological
   - PESTLE – Political, Economic, Social, Technological, Legal, Environmental
   - PESTLIED – Political, Economic, Social, Technological, Legal, International (or Informational), Environmental, Demographic
   - STEEPLE – Social, Technological, Economic, Environmental, Political, Legal, Ethics
   - InSPECT – Innovation, Social, Political, Economic, Communications, Technology
   - SPECTRUM – Socio-cultural, Political, Economic, Competitive, Technology, Regulatory/legal, Uncertainty/risk, Market
   - TECOP – Technical, Environmental, Commercial, Operational, Political
   - VUCA – Volatility, Uncertainty, Complexity, Ambiguity

4. Identify potential risks

   Identify and document all known risks, both threats and opportunities, related to the project within the identified planning horizon. Techniques such as brainstorming, interviews, cause and effect exercises, and checklists are effective tools to use during this step.

   Use a risk checklist to then further document and organize this preliminary list of identified risks. Table 29 shows an example risk checklist using some of the risk categories, factors of change, and potential impacts, as identified in Chapter 2. Modify the risk checklist to be project specific and update the checklist as the project progresses to include factors of change/risks identified throughout the planning process.

   As part of the risk identification process, evaluate the vulnerability of each asset identified in step 2. A transportation asset vulnerability table, similar to the one shown in Table 30, can be used to document and assess transportation asset vulnerability. See Appendix B for the full asset vulnerability table and an example of its use. Documentation should also include how important each asset is to achieving project outcomes.

Table 29. Example Risk Checklist

Factors of Change	Potential for Impact on					
	Assets	Revenue/ Funding	Land Use/ Development	Mobility	Equity	Safety
Population and Demographics						
Population growth						
Location preference and density						
Demographics						
Economy and Revenue						
Transportation revenues and spending						
Freight						
Transportation Investment, Equity, and the Economy						
Technology						
Automated and Connected Vehicles						
Ridesourcing and Ridesharing						
Alternative Fuels and Zero Emission Vehicles (ZEVs)						
Hyperloop						
Other Technological Advances						
Natural Hazards and Climate Change						
Sea level rise						
Hurricanes and tornadoes						
Flooding						
Extreme Heat						
Other natural hazards						

Table 30. Example Transportation Asset Vulnerability Table

Asset Categories	Assets	Risks								
		Technology				Natural Hazards/Climate				
		Automated and Connected Vehicles	Ridesourcing and Ridesharing	Alternative fuels and Zero Emission Vehicles	Hyperloop	Sea level rise	Extreme temperature	Increased precipitation and flooding	Wildfires	Extreme weather events
Highway	Pavement									
	Interchanges and intersections									
	Corridors									
Structure	Bridges and tunnels									
	Culverts									
	Mechanically stabilized earth (MSE) retaining walls									
	Ditches									
	Catch basins									
	Under/edge drains									
Safety	Barriers, i.e. Guard rails									
	Signals									
	Signs									
	Pavement markings									

Not vulnerable	○
Somewhat vulnerable	◑
Highly vulnerable	●

5. Evaluate risk

a) Assess the risks identified in step 4 to determine if they have the potential to affect project outcomes. Identify if the project is affected by threats or has the ability to take advantage of identified opportunities. Use existing projections and forecasts to identify the magnitude of risk. If projections or forecasts are not available, use existing literature, historical data, expert interviews, or brainstorming sessions to develop projections.

b) Use projections and forecasts to develop a set of project-specific indicators and thresholds of importance to the risk assessment (e.g., fleet turnover, sea level rise, etc.). The asset inventory developed in step 2 and the asset vulnerability table developed in step 4 can also be used to develop a set of indicators and thresholds for project-related assets.

c) Use findings from the risk checklist developed in step 4 to identify specific risk events. Input risk events into a risk register (or other risk assessment tool). Table 31 shows an example risk register, see Chapter 4 and Appendix D for a completed risk register and details on it use. Use results from the project-specific indicators and thresholds as a guide to scoring risk events. Risk level should be calculated using the formula:

Risk Level = Likelihood x Consequence x Vulnerability

Table 31. Example Risk Register

Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
Threats							
Opportunities							

Other tools to evaluate risk during this step may include a risk matrix, a risk scale, or risk mapping. Examples of these and additional tools can be found in Chapter 3.

d) Use available scenario analysis and studies, or perform new scenario analysis of alternative futures, to evaluate how the project will perform under different

future conditions. (NOTE: This could include scenarios developed for the FTP or MPO LRTP.)

e) Using results from the risk register completed in step 5(a) and the findings from the analysis of scenario plans or studies in 5(d), identify the vulnerability of the project to risk. If opportunities are high, overall risk levels from threats are low, and the project performs well under each scenario the analysis is complete. If opportunities are low, risk levels from threats are high, and/or the project does not perform well under all of the scenarios, adaptation options need to be developed.

Note: additional analysis during this step can include cascading effects using the CIrcle approach described in Chapter 3, or a similar tool.

6. Consequence management

Use outputs from the risk register to identify consequence management strategies for threats. More information on consequence management can be found Chapter 3. Strategies for threats may include the following:

- Avoid: Take proactive action to ensure the probability or impact of a risk is eliminated.
- Mitigate: Prepare contingency plans to mitigate the consequences of risks that cannot be eliminated or controlled due to cost or other reasons.
- Transfer: Shift responsibility to another party with authority to address the risk.
- Coordinate: Collaborate with other agencies or private sector to address potential risks.

Once a course of action is selected from the list of consequence management strategies, a risk treatment and adaptation plan can be developed. See Appendix C for an example risk treatment plan from the Transit New Zealand Risk Management Process Manual. Specific adaptation options depend on the project type, risk event types, level of risk, assets affected, and scenario criteria.

The following provides a description of criteria in the example risk treatment plan template:

- Alternative future/scenario - identify which alternative future/scenario the project did not perform well.
- Threat type – identify and describe the risk event.
- Level of risk – use the risk register to document the risk level calculated in step 5
- Consequence management strategy - document the consequence management strategies selected
- Treatment actions – list all actions needed to address the risk
- Responsibility – identify the individual or agency responsible for the treatment actions

- Timing – deadline for completion of treatment actions
- Resources – list resources needed to complete treatment actions
- Monitoring and Reporting – identify frequency of monitoring and type of reporting required
- Treatment cost – identify the estimated cost of treatment actions
- Threat reduction – identify a proposed estimate for reduction in risk following completion of the treatment

7. Reconsider Project
   If consequences are high and cannot be mitigated, or costs of mitigation/adaptation are too high, the project should be reconsidered and redefined or possibly terminated. If redefined, return to Step 1.

Risk Monitoring

At predetermined intervals and as new information becomes available, the project should be reassessed for new risks. Establish thresholds or benchmarks and monitor the project in relation to those thresholds. If, for example, it was determined that the project design would withstand certain flooding levels over its service life, does available information suggest that those levels may be exceeded earlier than anticipated? Are new design and drainage treatments becoming available that could extend that service life? These questions could be addressed in each key phase of the design process.

Chapter 7
Conclusions and Recommendations

A number of uncertainties and risks can arise in the next few decades that will require a planning response. Rapid changes in technology, environment, the economy, and society will result in a greater potential for disruption of transportation than has historically been the case. The collective set of uncertainties increases the prospect of inaccurate forecasts and ill-advised investments. Unlike traditional planning processes that predict and provide, long range planning in an era of high uncertainty will need to anticipate and adapt. This begins with identifying the most important drivers of change, and conducting exploratory scenario planning on the short- and long-term effects of alternative possible futures. This report has identified a number of drivers of change for this purpose (Appendix A).

The drivers of change include new mobility technologies and business models that could transform urban mobility, development patterns, social equity, and livability. Whether technology will help solve transportation challenges or simply create new ones, remains to be seen. The impacts of technology can be ones of opportunity or disruption, depending on the circumstances surrounding deployment and use. Various potential scenarios for the future of transportation can result from the interplay of these emerging technologies, and planning and policy responses to this uncertainty should allow for a change in course as new information emerges.

Now the third largest state in the U.S., Florida continues to grow approximately twice as fast as the nation as a whole. Whether Florida will continue to grow at this pace is another key uncertainty subject to a variety of economic, environmental, and policy considerations. Much of this growth has historically been fueled by in-migration of aging Baby Boomers and foreign persons, a trend that could change in the future. Nonetheless, the large cohort of aging Baby Boomers is an important issue for future transportation in Florida, as is the travel behavior of the high proportion of foreign-born immigrants and millennials.

Location preferences of new residents and how growth in these locations is managed in the future will continue to influence the magnitude and nature of travel demand. Generally, higher density urban development with a mix of uses in close proximity supports higher levels of walking, cycling and transit use, whereas, low-density suburban development and separation of land uses requires automobile travel. Whether Florida local governments will accommodate future growth and development in a manner that supports public transportation, walking and cycling is another key area of uncertainty for statewide planning.

Florida is also facing economic and revenue uncertainty or risk relative to statewide transportation planning. Key among these is a growing gap between transportation spending and user-based revenues. This gap is expected to accelerate with increased fuel efficiency. Questions continue to surround the federal role in resolving the funding crisis. Equity concerns surround both investment strategies and revenue generation schemes, such as congestion

pricing, tolls, and gas tax increases, which tend to be regressive in their impacts on lower income persons. Despite need for improved public transportation service, the response of travelers to public transportation service options during periods of economic growth versus decline and the ability to accomplish land use plans and first/last mile services to make these options efficient and economically viable are continued areas of uncertainty.

Finally, changes in the environment could dramatically affect Florida's transportation system, growth patterns, and economy. So much of the state has grown along the coast and in low lying areas, making Florida particularly vulnerable to rising temperatures that increase storm damage, flooding, and sea level rise. Road and rail closures, weather-related crashes, traffic disruptions, and impediments to evacuation routes are key short term impacts. Over the long term, increased flooding will result in the accelerated deterioration, erosion, and loss of the structural integrity of transportation infrastructure. Where growth and transportation assets are located, and the ability of planning and policy to adapt to these changes, will determine the resiliency of the state in response to these issues.

Threats and opportunities in an unknown future create risk and uncertainty in transportation planning. Projections and forecasts can provide some insight into future conditions, but with the ever-evolving nature of technology, the unpredictability of the environment caused by climate change, uncertainty regarding population and demographics, and increasingly diminished revenue sources, new ways to prepare for the future are needed.

The following are recommendations for further integrating risk and uncertainty into the long range transportation based on research findings:

1) **Encourage resiliency by integrating adaptive processes, consequence management strategies, and benchmarks/thresholds into planning processes.** Adaptive processes allow planning agencies to minimize risk and embrace uncertainty. With a feedback loop, the adaptive planning process provides opportunities to monitor and evaluate risks and assess the feasibility and effectiveness of planning decisions. Decision trees are well suited for adaptive processes because they inherently provide opportunities for frequent reevaluation and adjustment as new information is acquired. Within the adaptive planning process, consequence management strategies can be identified that provide flexible options to address the consequences of identified risks.
2) **Use risk registers to document risk and assess risk level during stakeholder engagement and throughout the planning process.** A risk register is a comprehensive list that describes the characteristics of risks, such as the likelihood of occurrence, the impact or consequences, the root causes, affected objectives, and overall risk rating. Risk registers can also include risk triggers, risk responsibility, and mitigation strategies. This tool helps an agency to crystallize the potential risks associated with a given course of action.

   Risk registers are easily integrated into existing planning processes and can be used in tandem with other risk identification and management tools. They are flexible in that

they can be used extensively or for guidance in the risk management process depending on an agency's specific needs. When used during stakeholder engagement, for example, risk registers can help stimulate meaningful discussions between participants and the facilitating agency.

3) **Use a decision-making focus and driving forces to develop scenarios for the FTP Vision Element.** To be effective in addressing risk, scenario development must be grounded in consideration of directional driving forces from which trends—however uncertain—can be projected and monitored in response to data and a desired future direction. Use of driving forces in scenario construction is essential for the scenarios to be useful for planning purposes. Without them, the planning implications of alternative futures cannot be evaluated.

   Effective scenarios also contain a clear focus on the outcomes sought by decision-makers. The decision-making focus offers guidance on how to use the scenarios in transportation planning processes. The scenarios can then be used for specific decision-making applications, such as where infrastructure investments should be made or what type of investments should be prioritized.

   An important finding from our analysis is that the alternative futures as presented in the FDOT FTP Vision Element are not constructed based on specified external driving forces. Nor do they embody a clear decision focus. It is unclear, therefore, how these futures can be used to guide planning and investment decisions, or to address risk and uncertainty.

   Goals and objectives in the FTP Policy Element provide a logical starting point to identify the decision focus for Florida specific scenarios. External driving forces, such as those identified in this research, and organizational driving forces should be prioritized in scenario development according to their level of predictability and importance in affecting the desired outcome. The next step is to flesh out each scenario based on lessons learned from the analysis.

   Once scenarios are developed, their content can be integrated into decision-making using the following steps:

   1) Study scenario implications and lessons learned.
   2) Choose indicators that help decision-makers monitor and react to changes in the external environment or developments in the project.
   3) Disseminate scenarios by refining them into easy-to-read language for use by implementing organizations.
   4) Integrate scenario outcomes into daily procedures by changing the incentive system in an affected agency to move toward the goals formed based on the scenario analysis.

Finally, scenario planning processes should integrate opportunities for monitoring and modification as new information becomes available. Furthermore, to ensure resiliency in Florida's transportation system, each scenario should account for natural disasters.

In sum, this research has identified a number of methods for addressing future risk and uncertainty in a long-range transportation planning context. The products of this research are a set of existing and conceptual methods, frameworks, and tools to mitigate risk at various levels of planning. Findings from this research can be used to assist FDOT in transportation planning efforts, particularly during the FTP update.

References

AASHTO. (2015). *Commuting in America 2013*. Retrieved from http://traveltrends.transportation.org/Pages/default.aspx.

AASHTO. (2016). *Public transportation: Survey of state funding. Final Report 2016 – FY 2014 Data.* Retrieved from https://www.azta.org/images/uploads/transit-studies/AASHTO_2016_Public_Transportation_Survey_of_State_Funding.pdf.

Airbus. (2017, Oct 3). "CityAirbus demonstrator passes major propulsion testing milestone." Retrieved from http://www.airbus.com/newsroom/press-releases/en/2017/10/cityairbus-demonstrator-passes-major-propulsion-testing-mileston.html.

American Planning Association. (2018). *Preparing Communities for autonomous vehicles.* Washington, DC: Jennifer Henaghan (Editor).

American Road and Transportation Builders Association (ARTBA). (2015). *The 2015 U.S. transportation construction industry profile*. Retrieved from https://www.transportationcreatesjobs.org/pdf/Economic_Profile.pdf

American Road and Transportation Builders Association (ARTBA). (2015). *The 2015 U.S. transportation construction industry profile.* Retrieved from http://www.transportationcreatesjobs.org/pdf/Economic_Profile.pdf.

American Trucking Association (ATA). (2012). *Forecast: U.S. freight transportation forecast to 2023.* Retrieved from http://www.azttca.org/pdf/ATA-Freight-Forecast.pdf.

Andersson, F., Haltiwanger, J. Kutzback, M, Pollakowski, H, and Weinberg, D. (April 2014). "Job displacement and the duration of joblessness: the role of spatial mismatch." NBER Working Paper Series, Working Paper 20066. National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w20066.pdf.

Aslam, A., Shah, A. (2017). "Taxation and the peer-to-peer economy." Retrieved from: https://www.imf.org/en/Publications/WP/Issues/2017/08/08/Taxation-and-the-Peer-to-Peer-Economy-45157.

Aven, T., & Renn, O. (2009). "On risk defined as an event where the outcome is uncertain." *Journal of risk research, 12(1),* 1-11.

Baig, A., Szewczyk, P., Valli, C., Rabadia, P., Hannay, P., Chernyshev, M., … Peacock, M. (2017). "Future challenges for smart cities: cyber-security and digital forensics." *Digital Investigation, 22*, 3-13.

Barry, J. M., & Caron, P. L. (2017). "Tax regulation, transportation innovation, and the sharing economy." *U. Chi. L. Rev. Dialogue,* 82, 69-84.

Bentley, J. & Collins, B. (2015). *Potential impacts of connected and autonomous vehicles thought piece [PDF Document].* Retrieved from https://at.govt.nz/media/1972362/potential-impacts-of-autonomous-and-connected-vehicles.pdf.

Berdica, K. (2002). “An introduction to road vulnerability: what has been done, is done and should be done.” *Transport policy, 9(2)*, 117-127.

Berry, L., Arockiasamy, M., Bloetscher, F., Kaisar, E., Rodriguez-Seda, J., Scarlatos, P., ... Hammer, N. M. (2012). *Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure. Florida Department of Transportation.* Retrieved from http://www.fdot.gov/research/Completed_Proj/Summary_PL/FDOT_BDK79_977-01_rpt.pdf.

Bloomberg New Energy Finance. (2018, May 21). “Electric vehicle outlook: 2018.” Retrieved from https://about.bnef.com/blog/e-buses-surge-even-faster-evs-conventional-vehicles-fade/

Blumenberg, E., & Taylor, B. D. (2018). “Millennial travel: who knows about kids these days?” Retrieved from Transfers Magazine: https://transfersmagazine.org/millennial-travel-who-knows-about-kids-these-days/?mc_cid=1e7eec26b3&mc_eid=f996bf180d.

Borgomero, E., Mortazavi-Naeini, M., Hall, J.W., & Guillod, B.P (2018). “Risk, robustness and water resources planning under uncertainty.” *Earth’s Future, 6*(3). Retrieved from https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017EF000730.

Bouton, S., Hannon, E., Knupfer, S., & Ramkumar, S. (2017). “The future(s) of mobility: How cities can benefit.” Retrieved from https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-futures-of-mobility-how-cities-can-benefit.

Bouton, S., Knupfer, S.M., Mihov, I., & Swartz, S. (2015). “Urban mobility at a tipping point.” Retrieved from https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/urban-mobility-at-a-tipping-point.

Brand, D., Mehndiratta, S. R., Parody, T. E. (2000). “Options approach to risk analysis in transportation planning.” *Transportation Research Record: Journal of the Transportation Research Board*, (1706), 54-63.

Braun, J., Sousa, J., & Pekardan, C. (2017). “Aerodynamic design and analysis of the hyperloop.” *AIAA Journal*, *55*, 4053-4060. DOI: 10.2514/1.J055634.

Brown, A., Blumenberg, E., Taylor, B. D., Ralph, K., & Voulgaris, C. T. (2016). “A taste for transit? Analyzing public transit use trends among youth.” *Journal of Public Transportation, 19(1), 49-67.*

Caltrans. (2007) *Project risk management handbook: threats and opportunities.* Retrieved from http://www.dot.ca.gov/hq/projmgmt/documents/prmhb/archive/caltrans_project_risk_management_handbook_20070502.pdf.

Caltrans. (2012). *Project risk management handbook: a scalable approach.* Retrieved from http://www.dot.ca.gov/hq/projmgmt/documents/prmhb/PRM_Handbook.pdf.

Chassignet, E. P., Jones, J. W., Misra, V., & Obeysekera, J. (Eds.). (2017). *Florida's climate: changes, variations, & impacts*. Gainesville, FL: Florida Climate Institute. https://doi.org/10.17125/fci2017.

Chu, T. H., Su, Y. "Will the U.S. auto market come back?" *Business Economics,* 45(4), 2010, 253–265.

City of San Antonio and Bexar County Office of Emergency Management. (2014). *Hazard identification, risk assessment (HIRA) and consequence analysis.* Retrieved from: http://www.saoemprepare.com/Portals/16/Files/Plans/planHIRA.pdf?ver=2017-02-28-235145-107.

Clark, B.Y., Larco, N., & Mann, R.F. (2017). *The impacts of autonomous vehicles and e-commerce on local government budgeting and finance [White Paper].* August 2017, from Source: https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/f/13615/files/2017/07/Impacts-of-AV-Ecommerce-on-Local-Govt-Budget-and-Finance-SCI-08-2017-2n8wgfg.pdf.

Congressional Budget Office, (2018) *Highway trust fund accounts—CBO's April 2018 baseline*. Retrieved from https://www.cbo.gov/sites/default/files/recurringdata/51300-2018-04-highwaytrustfund.pdf.

Cottam, B. (2018). "Transportation planning for connected autonomous vehicles: how it all fits together." *Journal of the Transportation Research Board*, 1-8.

Cotti, C. and Tefft, N. (2011). "Decomposing the relationship between macroeconomic conditions and fatal car crashes during the great recession: alcohol-and non-alcohol-related accidents." *The BE Journal of Economic Analysis & Policy*, 11(1).

Curtis, J., Dailey, J., D'angelo, D., DeWitt, S., Graf, M., Hankel, T. & Rocco, R. (2012). *Transportation risk management: International practices for program development and project delivery*. Retrieved from https://international.fhwa.dot.gov/scan/12029/12029_report.pdf.

D'Ignazio, J. (2011). *Executive strategies for risk management by state departments of transportation. [PDF Document].* Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-24(74)_ResearchReport.pdf.

D'Ignazio, J., Rhodes, S., & Secrest, C. (2015). *The role of planning in a 21st century state department of transportation – supporting strategic decisionmaking. [PDF Document].* Retrieved from https://www.nap.edu/download/22193.

Descant, S. (2018, May 18). "Think Uber and Lyft Are killing transit? Think again." *Government Technology.* Retrieved from http://www.govtech.com/fs/transportation/Think-Uber-and-Lyft-Are-Killing-Transit-Think-Again.html.

Dewar, J., Wachs, M. (2008). Transportation planning, climate change, and decisionmaking under uncertainity. Retrieved from http://onlinepubs.trb.org/onlinepubs/sr/sr290dewarwachs.pdf

Dimock, M. (2018). "Defining generations: where Millennials end and post-Millennials begin." *Fact Tank*.

Economic Development Research Group. (2018). "Uber's economic impacts in Florida." Retrieved from https://ubernewsroomapi.10upcdn.com/wp-content/uploads/2018/07/Florida-Uber-Report-.pdf

Edelman, B. G., & Geradin, D. (2015). "Efficiencies and regulatory shortcuts: How should we regulate companies like Airbnb and Uber." *Stan. Tech. L. Rev*., 19, 293. Retrieved from: https://www-cdn.law.stanford.edu/wp-content/uploads/2017/11/19-2-4-edelman-geradin-final.pdf.

Eidelson, J. (March 1, 2018). "U.S. income inequality hits a disturbing new threshold." Bloomberg Business. Retrieved from https://www.bloomberg.com/news/articles/2018-03-01/america-s-wage-growth-remains-slow-and-uneven.

Eising, J., van Onna, T., & Alkemade, F. (2014). "Towards smart grids: identifying the risks that arise from the integration of energy and transport supply chains." *Applied Energy,* 123, 448-455.

El-Karim, M. S. B. A. A., El Nawawy, O. A. M., & Abdel-Alim, A. M. (2015). "Identification and assessment of risk factors affecting construction projects." *HBRC Journal, 13*(2). 202-216.

Enterprise Florida. (2017). *2016 Florida international business highlights.* Retrieved from: https://www.enterpriseflorida.com/wp-content/uploads/report-florida-international-business-highlights.pdf.

Environmental Protection Agency (EPA). (2016). *What climate change means for Florida*. EPA 430-F-16-011. Retrieved from: https://www.epa.gov/sites/production/files/2016-08/documents/climate-change-fl.pdf.

Fagnant, D., & Kockelman, K. (2015). "Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendation." *Transportation Research Part A,* 77, 167-181.

Federal Highway Administration (FHWA). (2012a). *Report 1: overview of risk management*. *Risk-based transportation asset management: evaluating threats, capitalizing on opportunities*. Retrieved from: https://www.fhwa.dot.gov/asset/pubs/hif12035.pdf.

Federal Highway Administration (FHWA). (2012b). *Report 3: risks to asset management policies. Risk-based transportation asset management: evaluating threats, capitalizing on opportunities*. Retrieved from: https://www.fhwa.dot.gov/asset/pubs/hif12054.pdf.

Federal Highway Administration (FHWA). (2012c). *Transportation risk management: international practices for program development and project delivery*. Retrieved from https://international.fhwa.dot.gov/scan/12029/12029_report.pdf.

Federal Highway Administration (FHWA). (2013). *Generic Work Plan for Developing TAMP.* Retrieved from https://www.fhwa.dot.gov/asset/tamp/workplan.pdf.

Federal Highway Administration (FHWA). (2013). *Risk-Based Transportation Asset Management: Building Resilience into Transportation Assets.* Retrieved from https://www.fhwa.dot.gov/asset/pubs/hif13018.pdf.

Federal Highway Administration (FHWA). (2013). *Risk-Based Transportation Asset Management: Managing Risks to Networks, Corridors, and Critical Structures. U.S. Department of Transportation.* Retrieved from https://www.fhwa.dot.gov/asset/pubs/hif13017.pdf.

Federal Highway Administration (FHWA). (2016). *Adaptation Decision-Making Assessment Process (ADAP).* U.S. Department of Transportation. Retrieved from https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/adap/fhwahep17004.pdf.

Federal Highway Administration (FHWA). (2017a). *Vulnerability assessment and adaptation framework*. Retrieved from https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf.

Federal Highway Administration (FHWA). (2017b). *Incorporating risk management into transportation asset management plans.* Retrieved from https://www.fhwa.dot.gov/asset/pubs/incorporating_rm.pdf.

Federal Highway Administration (FHWA). (n.d.). *Efficient Transportation Decision-making (ETDM) Process (Florida).* Retrieved from https://fhwaapps.fhwa.dot.gov/planworks/Reference/CaseStudy/Show/3.

Federal Highway Administration (FHWA). *Supporting performance-based planning and programming through scenario planning. [PDF Document].* Retrieved from https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/fhwahep16068.pdf.

Filosa, G., Plovnick, A., Stahl, L., Miller, R., & Pickrell, D. (2018). *Vulnerability assessment and adaptation framework [PDF Document].* Federal Highway Administration. 3rd Edition. Retrieved from https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf.

FitchRatings. (April 3, 2018). *Global infrastructure & project finance, U.S. transportation trends.* Retrieved from: https://www.ibtta.org/sites/default/files/documents/2018/201804%20US%20Transportation%20Trends.pdf.

Florida Department of Transportation (FDOT). (2014). *Florida freight mobility and trade plan: investment element.* Retrieved from: http://www.floridaplanning.org/wp-content/uploads/2015/05/Freight-Mobility-and-Trade-Plan-COMPLETE.pdf.

Florida Department of Transportation (FDOT). (2015a) *Asset Management Plan.* Retrieved from http://www.fdot.gov/planning/TAMP/TAMP-2015.pdf.

Florida Department of Transportation (FDOT). (2015b). *Florida transportation asset management plan – technical report.* Retrieved from https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content/planning/tamp/technicalreport.pdf?sfvrsn=312138aa_0.

Florida Department of Transportation (FDOT). (2015c). *Florida Transportation Plan Vision Element.*

Florida Department of Transportation (FDOT). (2015d). *Florida Transportation Plan Policy Element.*

Florida Department of Transportation (FDOT). (2018a). *Guidance for Assessing Planning Impacts and Opportunities of Automated, Connected, Electric, and Shared-use Vehicles. Office of Policy Planning. [PDF Document].* Retrieved from http://www.planhillsborough.org/wp-content/uploads/2018/07/Revised-FDOT_MPO_ACES_PolicyGuide_May-2018.pdf.

Florida Department of Transportation (FDOT). (2018b). *FDOT planning process: components of plans and studies working draft revised 5/21/2018.* Retrieved from http://floridatransportationplan.com/planning-studies/pdf/FDOT%20PlnProc_Components%20of%20Plans%20and%20Studies_2018-05-21.pdf.

Florida Department of Transportation (FDOT). (n.d.a). *Transportation planning studies: how do we plan?* Retrieved from http://floridatransportationplan.com/planning-studies/WhyAndHowWePlan.htm#existing-conditions-info.

Florida Department of Transportation Office of Comptroller. (2017). *Transportation funding sources.* Retrieved from: http://www.fdot.gov/comptroller/pdf/GAO/RevManagement/TransportationFundingSources.pdf.

Florida Department of Transportation. (n.d.b). *Florida automated vehicles*. Retrieved from: http://www.automatedfl.com/Research-projects.html.

Florida Department of Transportation. (n.d.c). *Multi-modal freight data: sources and applications*. Retrieved from: http://www.fdot.gov/statistics/docs/MTF_Freight_Data_Subcommittee_Brochure.pdf.

Fuerth, L. S. (2009). "Foresight and anticipatory governance." *Foresight*, 11(4), 14-32.

Fulton, L., Mason, J., & Meroux, D. (2017). "Three revolutions in urban transportation." *Institute for Transportation & Development Policy*, *Davis, CA*.

Gallardo, R., Whitacre, B. (2018). *21st century economic development: telework and its impact on local income.* Retrieved from: https://onlinelibrary.wiley.com/doi/pdf/10.1111/rsp3.12117.

Georgia Department of Transportation (GDOT). (n.d.). *Transportation Asset Management Plan.* Retrieved from http://www.dot.ga.gov/PartnerSmart/Public/Documents/publications/Transportation%20Asset%20Management/TAMPlan.pdf.

Gershgorn, D. (2017, July 18). "Instead of hacking self-driving cars, researchers are trying to hack the world they see." Quartz. Retrieved from https://qz.com/1031233/instead-of-hacking-self-driving-cars-researchers-are-trying-to-hack-the-world-they-see/.

Ghilarducci, T., Papadopoulos, M. and Webb, A. (August 2017). "Inadequate retirement savings for workers nearing retirement." Policy Note: Schwartz Center for Economic Policy Analysis. Retrieved from: http://www.economicpolicyresearch.org/images/docs/research/retirement_security/Account_Balances_adjusted_appendix_tables.pdf.

Haasnoot, M., Kwakkel, J., Walker, W., & ter Maat, M. (2013). "Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world." *Global Environmental Change,* 23, 2: 485-498. Retrieved from https://www.sciencedirect.com/science/article/pii/S095937801200146X.

Hamilton, J. D. (2009). "Causes and consequences of the oil shock of 2007–08." *NBER Working Paper 15002.*

Hayden, C., and Cooper, S. (2008). "Disclosure and transparency in the automobile finance industry: a call for action." *One World Consulting Group, LLC, 1-23.*

Herrera, E. K., Flannery, A., & Krimmer, M. (2017). "Risk and resilience analysis for highway assets." *Transportation Research Record: Journal of the Transportation Research Board, (2604), 1-8.*

Hillsborough Metropolitan Planning Organization (MPO). (2014). *2040 Long Range Transportation Plan – Needs Assessment: Vulnerability Reduction Costs and Benefits.* Retrieved from http://www.planhillsborough.org/wp-content/uploads/2014/09/2040-LRTP-Vulnerability-Reduction-Tech-Memo.pdf.

Hillson, D. (2012). "Extending the risk process to manage opportunities." *International Journal of Project Management, 20*. 235-240.

Hillson, D. (2014). *Managing overall project risk.* Paper presented at PMI® Global Congress 2014—EMEA, Dubai, United Arab Emirates. Newtown Square, PA: Project Management Institute.

Hu, M., Monahan, S. (n.d.). *US E-commerce Trends and the Impact on Logistics*. Retrieved from https://www.atkearney.com/retail/article?/a/us-e-commerce-trends-and-the-impact-on-logistics.

Hyperloop One. (2017) *Winning route: United States Miami – Orlando.* Retrieved from https://hyperloop-one.com/global-challenge-winners/#florida.

Institute on Taxation and Economic Policy (ITEP). (September 2013). *A Federal Gas Tax for the Future*. Retrieved from https://itep.org/wp-content/uploads/fedgastax0913.pdf.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Investopedia. (n.d.) “Sharing Economy.” Retrieved from https://www.investopedia.com/terms/s/sharing-economy.asp.

Irwin, J. (2018, July 26). “Florida Uber drivers raked in nearly $900 million last year.” *Tampa Bay Business Journal*. Retrieved from https://www.bizjournals.com/tampabay/news/2018/07/26/florida-uber-drivers-raked-in-nearly-900-million.html.

Iseki, H., Smart, M., Taylor, B. D., & Yoh, A. (2012). “Thinking outside the bus.” *Access Magazine,* 40. Retrieved from https://www.accessmagazine.org/wp-content/uploads/sites/7/2016/01/access40_outsidethebus.pdf.

James, O. (2018, June 14). “When it comes to AVs, why is no one talking about induced demand?” Mobility Lab. Retrieved from https://mobilitylab.org/2018/06/14/when-it-comes-to-avs-why-is-no-one-talking-about-induced-demand/.

Jeuken, C., Burzel, A., Bruijn, K., Jurado, J., Danchuk, S., Maran, C., … Obeysekera, J. (2019). *Critical infrastructure networks of Broward County*. Retrieved from http://circle-cifre.nl/downloads/Overall%20workshop%20report%20CIFRe%20project.pdf.

Kato, S. & Ahren, J. F. (2008). “’Learning by doing’: Adaptive planning as a strategy to address uncertainty in planning.” Scholar Works at UMass Amherst. [PDF Document]. Retrieved from https://scholarworks.umass.edu/larp_grad_research/15/.

Khadka, S. (2015). *Project Risk Management: Integrating it in transportation projects from planning through design and construction to minimize cost and schedule overruns.* Ohio Department of Transportation. [PDF Document]. Retrieved from http://www.dot.state.oh.us/engineering/OTEC/2015_OTEC_Presentations/Tuesday_Oct.27/15/Khadka_Hyland_15_FinalDraft.pdf.

Kirk, R. (August 4, 2017). “Tolling U.S. highways and bridges.” *Congressional Research Service Report*. Retrieved from https://www.ibtta.org/sites/default/files/documents/2017/CRS%20Interstate%20tolls_2017-08-04.pdf.

Kwakkel, J.H., Walker, W.E., Marchau, V.A.W.J. (2010). *Adaptive airport strategic planning.* Retrieved from http://www.ejtir.tudelft.nl/issues/2010_03/pdf/2010_03_03.pdf.

Lakeshore Realty. (2014). “Could lower energy prices stimulate housing demand?” Retrieved from http://www.lakeshorerealty.com/2014/12/01/could-lower-energy-prices-stimulate-housing-demand/.

Lee, J. Y., Burton, H. V., & Lallemant, D. (2018). “Adaptive decision-making for civil infrastructure systems and communities exposed to evolving risks.” *Structural Safety,* 1-12. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877705818300742.

Lee, T. (March 7, 2018). *Testimony prepared for the Subcommittee on Highways and Transit, Transportation and Infrastructure Committee, U.S. House of Representatives.* Economic Policy Institute. Retrieved from https://transportation.house.gov/uploadedfiles/2018-03-07_-_lee_testimony.pdf.

Lempert, R. (2013). “Scenarios that illuminate vulnerabilities and robust responses.” *Climatic Change*, (117), 627–646.

Levinson, D., Boies, A., Cao, J., & Fan, Y. (2016). *The transportation futures project: planning for technology change [White Paper].* Retrieved from: https://www.aamva.org/PlanningForTechChanges_MNDOT_012016/.

Litman, T. (2017) “Autonomous vehicle implementation predictions implications for transport planning.” *Victoria Transport Policy Institute, 1-23.* Retrieved from https://www.vtpi.org/avip.pdf.

Livingston, G. (2018). “Is U.S. fertility at an all-time low? It depends.” *Fact Tank*.

Logistics Management. (2018). *The E-commerce Logistics Revolution*. Retrieved from: https://www.logisticsmgmt.com/article/the_e_commerce_logistics_revolution.

Lutin, J. (2013). *Opportunities to leverage advances in driverless car technology to evolve conventional bus transit systems [Powerpoint slides].* Retrieved from http://orfe.princeton.edu/~alaink/SmartDrivingCars/LutinFinalPodCarCity7DraftPresentation_192413.pptx.

Lyft. (n.d.). “Cities we’re In.” Retrieved from https://www.lyft.com/cities.

Lyons, G. & Davidson, C. (2016). “Guidance for transport planning and policymaking in the face of an uncertain future.” *Transportation Research Part A, 88*, 104-116. Retrieved from https://www.sciencedirect.com/science/article/pii/S0965856416302555.

Lyons, G., Mokhtarian, P., Dijst, M., & Böcker, L. (2018). “The dynamics of urban metabolism in the face of digitalization and changing lifestyles: understanding and influencing our cities.” *Resources, Conservation & Recycling, 132, 246-257.*

Maack, J.N. (2001). *Scenario Analysis: A Tool for Task Managers.* World Bank, Washington, DC, pp. 62–87.

Machado-León, J. L., & Goodchild, A. (2017). “Review of performance metrics for community-based planning for resilience of the transportation system.” *Transportation Research Record*, *2604*(1), 44-53.

Maheshri, V., & Winston, C. (2016). “Did the great recession keep bad drivers off the road?” *Journal of Risk and Uncertainty, 52(3), 255-280.*

Major, D. C., & O’Grady, M. (2010). “Adaptation assessment guidebook.” *Annals of the New York Academy of Sciences, 1196*(1), 229-292.

Marchau, V. A. W. J., Walker, W. E., & van Wee, G. P. (2010). “Dynamic adaptive transport policies for handling deep uncertainty.” *Technological Forecasting & Social Change, 77*, 940 – 950. Retrieved from https://www.sciencedirect.com/science/article/pii/S0040162510000739 .

McCahill, C. (2015). “For the first time in a decade, U.S. per capita highway travel ticks up.” State Smart Transportation Initiative. Retrieved from https://www.ssti.us/2015/03/for-the-first-time-in-a-decade-u-s-per-capita-highway-travel-ticks-up/.

McFarland, M. (2018, June 7). “Self-driving cars. Scooters. The future of commuting to work is here.” Retrieved from http://www.wfmz.com/news/selfdriving-cars-scooters-the-future-of-commuting-to-work-is-here/750238803.

Meister, J., Lepofsky, A., and ZoBell, S. (n.d.a.). *Engaging 5 generations in the future workplace — Part 1.* Retrieved on 08/03/2018 from https://www.workfront.com/blog/engaging-5-generations-in-the-future-workplace-part-1.

Melillo, Jerry M., Richmond, T.C., and Yohe G.W., (2014). “Climate change impacts in the United States: the third national climate assessment.” *U.S. Global Change Research Program*. doi:10.7930/J0Z31WJ2.

Metropolitan Planning Organization Advisory Council (MPOAC). (2011). *Florida situational analysis: an analysis of transportation funding in the State of Florida.* Retrieved from http://archive.browardmpo.org/userfiles/files/Transportation%20Funding%20in%20FL%20Situational%20Analysis_Draft1_5_11.pdf.

Metropolitan Transportation Commission. (n.d.). “Plans + Projects.” Retrieved from https://mtc.ca.gov/our-work/plans-projects/horizon.

Meyer, M., Flood, M., Keller, J., Lennon, J., McVoy, G., Dorney, C., ... & Smith, J. (2014). *Strategic issues facing transportation, volume 2: climate change, extreme weather events, and the highway system: practitioner’s guide and research report* (No. Project 20-83 (5)).

Meyer, M.D. (2007). *U.S. domestic scan program: best practices in transportation asset management*. Retrieved from http://onlinepubs.trb.org/onlinepubs/trbnet/acl/ncrhp2068_domestic_scan_tam_final_report.pdf.

Miami-Dade TPO. (December 2017). *First mile-last mile: options with high trip generator employers.* Prepared by the Corradino Group. Retrieved from http://www.miamidadetpo.org/library/studies/first-mile-last-mile-options-with-high-trip-generator-employers-2017-12.pdf.

Miami-Dade TPO. (June 2017). *Impact of future technology in the 2045 LRTP.* Prepared by the Corradino Group. Retrieved from http://www.miamidadetpo.org/library/studies/impact-of-future-technology-in-the-2045-lrtp-final-report-2017-06.pdf.

Miller, S. R. (2016). “First principles for regulating the sharing economy.” *Harvard Journal on Legislation, 53, 147*. Retrieved from http://harvardjol.com/wp-content/uploads/2016/02/HLL107_crop.pdf.

Milly, P. C., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. (2008). “Stationarity is dead: whither water management?” *Science,* 319(5863), 573-574.

Minnesota Department of Transportation. (2014). *Transportation Asset Management Plan. [PDF Document]*. Retrieved from https://www.dot.state.mn.us/assetmanagement/pdf/tamp/tamp.pdf.

Misra, V., Carlson, E., Craig, R. K., & Enfield, D. (2011). *Climate scenarios: a Florida-centric view*. Retrieved from http://www.floridawca.org/sites/default/files/documents/climate_scenario.pdf.

Mokhtarian, P. (2004). A conceptual analysis of the transportation impacts of B2C e-commerce. *Transportation*, 31, 257-284.

Molenaar, K., Anderson, S., Schexnayder, C. (2010). Guidebook on risk analysis tools and management practices to control transportation project costs. Retrieved from http://www.trb.org/Publications/Blurbs/163722.aspx.

National Association of City Transportation Officials. (2017). *Bike share in the U.S.: 2017, NACTO Bike Share Initiative*. Retrieved from https://nacto.org/bike-share-statistics-2017.

National Association of Realtors. (2017). *National community and transportation preferences survey.* Retrieved from https://www.nar.realtor/sites/default/files/documents/2017%20Analysis%20and%20slides.pdf.

National Highway Traffic Safety Administration (NHTSA). (n.d.) *Automated Vehicles for Safety.* Retrieved from https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety#topic-road-self-driving.

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental information. (2018a). *Climate at a glance: statewide time series*. Retrieved from https://www.ncdc.noaa.gov/cag/.

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental information. (2018b). *U.S. Billion-dollar weather and climate disasters.* Retrieved from https://www.ncdc.noaa.gov/billions/.

National Oceanic and Atmospheric Administration (NOAA) National Weather Service. (2017). *2017 summary of hazardous weather fatalities, injuries, and damage costs by state.* Retrieved from http://www.nws.noaa.gov/om/hazstats/state17.pdf.

New Jersey Department of Transportation. (n.d.). *Capital Project Delivery Risk Management.* Retrieved from https://www.state.nj.us/transportation/capital/pd/process_riskmgt.shtm.

New York State Department of Transportation. (2009). *Risk management guide for project development.* Retrieved from https://www.dot.ny.gov/divisions/engineering/design/dqab/dqab-repository/Risk%20Management%20for%20Project%20Development%20Guide_Final%20Draft_010514_0.pdf.

NSW Treasury. (2012). *Risk Management Toolkit for MSW Public Sector Agencies. Volume 1: Guidance for Agencies [PDF Document].* Retrieved from https://www.treasury.nsw.gov.au/information-public-entities/governance-risk-and-assurance/internal-audit-and-risk-management/risk.

Oei, S. Y., & Ring, D. M. (2015). "Can sharing be taxed?" *Wash. UL Rev.,* 93, 989. Retrieved from: https://openscholarship.wustl.edu/law_lawreview/vol93/iss4/7/.

Office of Economic & Demographic Research. (2018). *Florida economic summary: Florida economic estimating conference.* Retrieved from http://edr.state.fl.us/Content/conferences/fleconomic/floridaeconomicsummary.pdf.

Ohio Department of Transportation (Ohio DOT). (2011). *Transportation Asset Management Recommendations Report.* Retrieved from http://www.dot.state.oh.us/Divisions/Planning/TechServ/Documents/TAM%203.2.11.pdf

Ohio State University. (n.d.). "The benefits and challenges of the unmanned aerial vehicle." Retrieved from https://onlinemasters.ohio.edu/the-benefits-and-challenges-of-uavs/?g=infographics&t=msee.

Oswald, M., & Treat, C. (2013). "Assessing public transportation vulnerability to sea level rise: a case study application." *Journal of Public Transportation*, 16(3), 4.

Paladin Risk Management Services. (n.d.). "Developing a consequence matrix." Retrieved on 7/10/2018 from https://paladinrisk.com.au/risk-tip-3-developing-consequence-matrix/.

Perseus. (n.d.). Qualitative risk analysis (consequence x likelihood). Retrieved from http://www.perseus-net.eu/site/content.php?artid=2204

Polzin, S. (2016). *Implications to public transportation of emerging technologies*. National Center for Transit Research. Retrieved from https://www.nctr.usf.edu/wp-content/uploads/2016/11/Implications-for-Public-Transit-of-Emerging-Technologies-11-1-16.pdf.

Polzin, S., Godfrey, J., & Chu, X. (2014). "The impact of millennials' travel behavior on future personal vehicle travel." *Energy Strategy Reviews*, 5.

Prevost, C. (2018) "The sharing economy: six disruptions on the transportation ecosystem." *Freight Waves*.

Proctor, G., Varma, S., Roorda, J. (2016). *Managing risk across the enterprise: a guide for state departments of transportation.* Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-93_FullGuide.pdf.

Quay, R. (2010). "Anticipatory governance: a tool for climate change adaptation." *Journal of the American Planning Association*, 76(4), 496-511.

Quay, R. (2018, April). *Planning in an age of uncertainty*. Symposium conducted at the American Planning Association National Planning Conference, New Orleans, LA.

Rasool, M., Franck, T., Denys, B., & Halidou, N. (2012). "Methodology and tools for risk evaluation in construction projects using Risk Breakdown Structure." *European Journal of Environmental and Civil Engineering*, 16. 78-98. Retrieved from https://doi.org/10.1080/19648189.2012.681959.

Rutter, A., Bierling, D., Lee, D., Morgan, C., Warner, J. (2017). "How will e-commerce impact our transportation network?" Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-79-F.pdf.

San Diego Association of Governments. (2018). “Emerging technologies.” Retrieved from https://www.sdforward.com/mobility-planning/emerging-technologies.

Saussier, J. (2015). “Sharing as a disruptive force.” *Global Inventor 2.15.* Retrieved from https://www.oxfordmartin.ox.ac.uk/downloads/GI_215_e_GesamtPDF_01_high.pdf

Schiller, Z., Davis, C. (2017). “Taxes and the on-demand economy.” Retrieved from https://itep.org/wp-content/uploads/ondemandeconomytaxes0317.pdf.

Schweitzer, L., & Taylor, B. (November 2008). “Just pricing: the distributional effects of congestion pricing and sales taxes.” *Transportation*, 35(6), 797–812.

Seggerman, K. and Kramer, J. (April 2013) *Review of MPO Long Range Transportation Plans and Estimate of Statewide 2035 Metropolitan Area Financial Shortfall*. Center for Urban Transportation Research.

Shaheen, S. & Cohen, A. (2018). “Is it time for a public transit renaissance?” *Journal of Public Transportation,* 21, 67-81.

Shaheen, S., Cohen, A., & Jaffee, M. (2018). “Innovative mobility: carsharing outlook.” *Carsharing Market Overview, Analysis, and Trends.* Transportation Sustainability Research Center, University of California – Berkeley. Retrieved from https://escholarship.org/uc/item/49j961wb.

Shaheen, S., Totte, H. & Stocker, A. (2018). *Future of mobility [White Paper].* April 26, 2018. Retrieved from http://www.dot.ca.gov/hq/tpp/offices/osp/future-of-mobility.pdf.

Shared-Use Mobility Center (2016). *Shared Mobility and the Transformation of Public Transit: Research Analysis.* Retrieved from: https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf.

Shergold, I., Lyons, G., & Hubers, C. (2015). “Future of mobility in an aging society – where are we heading?” *Journal of Transport and Health (2),* 86-94.

Smith, S. (February 25, 2015). “The baby boom and the aging of Florida’s population.” Bureau of Economic and Business Research, University of Florida. Retrieved from https://www.bebr.ufl.edu/population/website-article/baby-boom-and-aging-florida%E2%80%99s-population.

Sorensen, P. (2014). *Strategic issues facing transportation, volume 5: preparing state transportation agencies for an uncertain energy future.* Retrieved from http://nap.edu/22378.

Sorenson, P. (2013). “From fuel taxes to mileage fees.” *Access*, Number 43, Fall 2013. University of California.

SpaceX. 2013. “Hyperloop Alpha.” Retrieved from http://www.spacex.com/sites/spacex/files/hyperloop_alpha-20130812.pdf.

Stanford Center on Poverty & Inequality (2011). "20 facts about U.S. inequality that everyone should know." Retrieved from https://inequality.stanford.edu/publications/20-facts-about-us-inequality-everyone-should-know.

State Smart Transportation Initiative (SSTI). (2012). "Transit ridership continues upward trend in 2011." Retrieved from https://www.ssti.us/2012/03/transit-ridership-continues-upward-trend-in-2011/.

Stern, R., Cui, S., Delle Monache, M.L., Bhadani, R., Bunting, M., Churchill, M.,… Work, D.B. (2017). "Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments." *Transportation Research Part C: Emerging technologies, 89,* 205-221. Retrieved from https://arxiv.org/pdf/1705.01693.pdf.

Stone, T. (Ed.). (2018). "The future of transportation executive briefing 2018: mobility solutions 2020-2030 and beyond!" *The International Review of Future Transportation Concepts and Technologies.* Retrieved from http://viewer.zmags.com/publication/5c1843a2#/5c1843a2/1.

Strauss, B., C. Tebaldi, S. Kulp, S. Cutter, C. Emrich, D. Rizza, and D. Yawitz (2014). "Florida and the surging sea: a vulnerability assessment with projections for sea level rise and coastal flood risk." *Climate Central Research Report*. pp 1-58.

Swanson, D., Barg, S., Tyler, S., Venema, H., Tomar, S., Bhadwal, S.,… Drexhage, J. (2010). "Seven tools for creating adaptive policies." *Technological Forecasting and Social Change, 77,* 924-939. Retrieved from https://www.sciencedirect.com/science/article/pii/S0040162510000727.

Taneja, P., Vellinga, T. & Sol, S. R. (2014). "Planning and management of port infrastructure projects under uncertainty." *Vulnerability, Uncertainty, and Risk*, 378-388. Retrieved from https://ascelibrary.org/doi/pdf/10.1061/9780784413609.039.

Taylor, M. (2017). *Vulnerability analysis for transportation networks*. Elsevier. Retrieved from https://www.sciencedirect.com/science/book/9780128110102.

The Florida Legislature Office of Economic and Demographic Research. (2018). *Florida: An Economic Overview* [PowerPoint Slides]. Retrieved from http://edr.state.fl.us/Content/presentations/economic/FlEconomicOverview_2-7-18.pdf.

The Future of Transportation Executive Briefing. (2018). "Mobility Solutions 2020-2030 and Beyond." *The International Review of Future Transportation Concepts and Technologies*. Retrieved from http://viewer.zmags.com/publication/5c1843a2.

Tomer, A. (July 11, 2012). "Where the jobs are: Employer access to labor by transit." *Brookings Report*. Retrieved from https://www.brookings.edu/research/where-the-jobs-are-employer-access-to-labor-by-transit/.

Tomer, A. (May 9, 2018). "Can people afford American infrastructure?" *The Avenue: Brookings*. Retrieved from https://www.brookings.edu/blog/the-avenue/2018/05/09/can-people-afford-american-infrastructure/.

Transit New Zealand. (2004). *Risk management process manual.* Retrieved from https://www.nzta.govt.nz/assets/resources/risk-management-process-manual/docs/risk-management-process-manual.pdf.

Transportation Research Board and National Research Council (TRB). 2008. *Potential impacts of climate change on U.S. transportation: Special Report 290.* Washington, DC: The National Academies Press. Retrieved from https://doi.org/10.17226/12179.

Transportation Research Board Executive Committee. (2013). *Critical Issues in Transportation*. Washington D.C.: Transportation Research Board of the National Academies.

Twaddell, H., McKeeman, A., Grant, M., Klion, J., Avin, U., Ange, K., & Callahan, M. (2016). *Supporting Performance-Based Planning and Programming through Scenario Planning. Federal Highway Administration. [PDF Document].* Retrieved from https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/fhwahep16068.pdf.

U.S. Census Bureau. (2010). American community survey. Retrieved from https://www.census.gov/programs-surveys/acs/data/summary-file.2010.htmlU.S. Census Bureau. (2016). *American community survey*. Retrieved from https://www.census.gov/acs/www/data/data-tables-and-tools/supplemental-tables/.

U.S. Census Bureau. (2018). *E-Stats 2016: measuring the electronic economy.* Retrieved from https://www.census.gov/content/dam/Census/library/publications/2018/econ/e16-estats.pdf.

U.S. Census Bureau. (n.d.). State-to-state migration flows. Retrieved from https://www.census.gov/data/tables/time-series/demo/geographic-mobility/state-to-state-migration.html

U.S. Department of Commerce. (May 2018). "Quarterly retail e-commerce sales: 1st quarter 2018." *U.S. Census Bureau News.* Retrieved from https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf.

U.S. Department of Homeland Security (DHS). (2010). *DHS risk lexicon.* Retrieved from: https://www.dhs.gov/dhs-risk-lexicon.

U.S. Department of Transportation (n.d.). *Climate adaptation plan: ensuring transportation infrastructure and system resilience.* U.S. Department of Transportation.

U.S. Department of Transportation (USDOT) & Bureau of Transportation Statistics (BTS). (2017a). *Freight facts and figures 2017.* Retrieved from https://www.bts.gov/sites/bts.dot.gov/files/docs/FFF_2017.pdf.

U.S. Department of Transportation (USDOT) & Bureau of Transportation Statistics (BTS). (2017b). *Freight analysis framework, version 4.4*. Retrieved from https://www.bts.gov/newsroom/florida-freight-impact.

U.S. Department of Transportation (USDOT). (2015). *State Transportation by the numbers: a compendium of state summaries*. Retrieved from https://www.bts.gov/sites/bts.dot.gov/files/legacy/_entire.pdf.

U.S. Energy Information Administration. (2018). *Annual energy outlook 2018 with projections for 2050*. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf.

U.S. Environmental Protection Agency. (2017). *Trends shaping the future of freight*. Retrieved from https://www.epa.gov/sites/production/files/2017-04/documents/sw-feight-trends-2017-03-29.pdf.

U.S. Government Accountability Office (GAO). (2017). "Key issues - funding the nation's surface transportation system - high risk issue." Retrieved on 05/14/2018 from https://www.gao.gov/key_issues/funding_nations_surface_transportation_system/issue_summary.

Uber Elevate. (2016, October 27). "Fast-forwarding to a future of on-demand urban air transportation." Retrieved from https://www.uber.com/elevate.pdf.

Uber. (2014, December 4). "Uber is expanding across the Sunshine State!" Retrieved from https://www.uber.com/blog/florida/uber-florida-is-expanding-across-the-sunshine-state-3/.

University of Cambridge. (n.d.) "Analyze risk." *SSA Toolkit*. Retrieved from http://www.ssatoolkit.com/ssatoolkit/assess3assess/.

University of Florida GeoPlan Center. (n.d.). *Sea Level Scenario Sketch Planning Tool*. Retrieved from https://sls.geoplan.ufl.edu/.

Ushakova, G. (2017, April 20). "Connecting Orlando with Miami Beach." *Virgin Hyperloop-One.* Retrieved from https://hyperloop-one.com/blog/connecting-orlando-miami-beach.

Victoria State Emergency Service. (2018). *Community Emergency Risk Assessment: Informing Emergency Management Planning. [PDF Document].* Retrieved from https://www.ses.vic.gov.au/documents/112015/137120/CERA+Workbook-pdf/caf49e53-92f4-4c8e-bc07-d0e3e485d74e.

Victoria State Government. (2018). *Victorian Government Risk Management Framework. [PDF Document].* Retrieved from https://www.dtf.vic.gov.au/sites/default/files/document/VGRMF%20- U.S. Department of Homeland Security. (2010). DHS risk lexicon. Retrieved from: https://www.dhs.gov/dhs-risk-lexicon %20July%202018%20update_0.pdf.

Virginia Department of Transportation (VDOT), University of Virginia (UVA), Virginia Center for Transportation Innovation and Research (VCTIR), Hampton Roads Planning District Commission (HRPDC), Hampton Roads Transportation Planning Organization (HRTPO). (2012). *Assessing Vulnerability and Risk of Climate Change Effects on Transportation Infrastructure.* Retrieved from http://www.virginia.edu/crmes/fhwa_climate/files/finalReport.pdf.

Wachs, M. (2011). "Transportation, jobs, and economic growth." *Access,* Number 38: Spring 2011.University of California.

Wadud, Z., Mackenzie, D., and Leiby, P. (2016). "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles." *Transportation Research Part A: Policy and Practice*, 86, 1-18.

Walker, W. E., Marchau, V.A., & Swanson, D. (2010). "Addressing deep uncertainty using adaptive policies: Introduction to section 2." *Technological Forecasting and Social Change, 77*, 917 – 923. Retrieved from https://www.sciencedirect.com/science/article/pii/S0040162510000715.

Ward, S. and Chapman, C. (2003). *Project risk management: Processes, Techniques, and Insights, Second Edition.* West Sussex, England: John Wiley & Sons, Ltd. Retrieved from http://index-of.co.uk/Project%20Management/John%20Wiley%20&%20Sons%20-%20Project%20Risk%20Management%20-%20Processes_%20Techniques%20&%20Insights.pdf

Washington State Department of Transportation (WSDOT). (2014). *Project Risk Management Guide*. Retrieved from http://www.wsdot.wa.gov/publications/fulltext/cevp/projectriskmanagement.pdf.

Wilson, I. (1998). "Mental Maps of the Future: An Intuitive Logics Approach to Scenarios." *In Learning from the Future: Competitive Foresight Scenarios.* 81-108.

WSDOT. (2011). *Climate Impacts Vulnerability Assessment.* Retrieved from: https://www.wsdot.wa.gov/sites/default/files/2017/11/15/ENV-Climate-VulnerabilityAssessment.pdf.

Zmud, J. P., Barabba, V. P., Kuzmyak, J. R., Zmud, M., & Orrell, D. (2014). "Strategic issues facing transportation, volume 6: the effects of socio-demographics on future travel demand." *National Cooperative Highway Research Program.* Washington, D.C.: Transportation Research Board.

Zmud, J., Goodin, G., Moran, M., Kalra, N. & Thorn, E. (2017). "Advancing automated and connected vehicles: policy and planning strategies for state and local transportation agencies." *Transportation Research Board*. Retrieved from http://nap.edu/24872..

Zmud, J., Tooley, M., Baker, T., & Wagner, J. (2015). "Paths of automated and connected vehicle deployment: Strategic roadmap for state and local transportation agencies." *Texas A&M Transportation Institute*. Retrieved from https://static.tti.tamu.edu/tti.tamu.edu/documents/161504-1.pdf.

Appendix A
Overview of Uncertainties and Potential Impacts

Table A- 1. Overview of Uncertainties and Potential Impacts

Category	Drivers of Change	Trends	Uncertainties/Risks	Potential Impacts
Population and Demographics	**Population Growth** In-migration and immigration	Rapid growth (third largest state, most growth in Florida due to migration)	▪ Sustainability of growth	➢ Intensification of travel demand ➢ Need for more mobility options
	Location Preference and Density Choice of area types (urban, suburban, rural) and housing type	Growing density (91% of Floridians reside in urban areas); increase in multi-family housing	▪ Urban preference/focused growth vs. suburban preference/dispersed growth ▪ Interior vs. coastal growth	➢ Rapid growth of core areas ➢ Densities more conducive to transit use, except in dispersed areas ➢ More non-auto trips ➢ Coastal growth increases vulnerability
	Demographics Silent generation, Baby boomers, Millennials, Gen Z	Delayed life milestones of millennials Growing proportion of elderly (7.4 million Floridians will be 65 or older by 2050) Delayed retirement, caregiving roles, women in labor force	▪ Millennial and Gen Z travel behavior ▪ Safe mobility options for aging population	➢ Continued auto demand ➢ Increased need for safe alternatives to driving ➢ Growing demand for walkable places ➢ Growing use of mobility as a service
Natural Hazards and Climate Change	**Natural Hazards and Climate Change** wildfires, extreme heat, sea level rise, hurricanes and tornadoes, storms, flooding	Gradual warming trend, increase in wildfires, extreme precipitation events, flooding and sea level rise	▪ Location and extent of damage ▪ Degree of economic disruption ▪ Timing and degree of sea level rise ▪ Mitigation of impacts on coastal areas ▪ Assets at greatest risk	➢ Road and rail closures, airline delays and cancellations, weather-related crashes, traffic disruptions, impediments to evacuation routes, limited construction activities ➢ Economic disruption and decline ➢ Development pressure shifts away from coast into interior areas

Category	Drivers of Change	Trends	Uncertainties/Risks	Potential Impacts
Technology	**Automated and Connected Vehicles** Deployment, timing, capacity, fleet turnover	Industry advancement and maturation of AV technology AV/CV testing and leadership in Florida Increasing age of vehicles slowing fleet turnover	▪ Impact on mobility, safety, system capacity, and land use ▪ Rate of deployment and adoption ▪ Infrastructure needs ▪ Cybersecurity	➢ Smarter roads and vehicles ➢ Could increase vehicle miles of travel, lead to urban sprawl ➢ Could increase transit efficiency or reduce ridership ➢ Opportunity to repurpose right of way ➢ Reduced surface parking, but increased need for curb space ➢ May reduce crashes, congestion, and air pollution ➢ CV infrastructure costs outpace funding resources
	Ridesourcing and Ridesharing TNCs (Uber, Lyft), carshare, bikeshare, ICT	Growing use of ridesourcing and ridesharing services. Evidence of TNCs as both partner and competitor to transit Emergence of sharing economy	▪ Rate of expansion of ridesourcing and ridesharing ▪ Impacts on car ownership ▪ Impacts on public transportation	➢ Dramatic expansion of sharing economy ➢ May complement or compete with public transportation ➢ Potential to reduce car ownership ➢ Multimodal integration ➢ ICT facilitates multimodal integration
	Alternative Fuels and Zero Emission Vehicles (ZEVs) cost, infrastructure	Growth in EVs and recharging locations Increasing diversity of fuels	▪ Potential to replace or overtake petroleum ▪ Impact on revenues ▪ Availability of infrastructure	➢ Variable depending on fuel type ➢ Reduction in gas tax revenues ➢ Reduced emissions
	Hyperloop	Preliminary development and corridor identification, including Orlando to Miami in Florida.	▪ Viability of system ▪ Impacts on long distance travel modes ▪ Cost ▪ Impact on built environment	➢ Dramatically shorter long-distance travel times ➢ Increased commuting distances ➢ Greater economic productivity ➢ Immune to weather and self-powering
	Other Technological Advances e-bikes, flying cars, UAVs, big data, 3-D printing, etc.	A variety of technologies and data sources are emerging or expected to emerge	▪ Impact on mobility, safety, infrastructure ▪ Impact on mode choice ▪ Impact on construction costs	➢ Decreased production and construction costs (3-D printing) ➢ Safety and environmental impacts of UAVs, flying cars ➢ Improved ability for demand management

Category	Drivers of Change	Trends	Uncertainties/Risks	Potential Impacts
Economy and Revenue	**Transportation Revenues and Spending** Taxes and funding for transportation projects , federal and state roles, alternative revenues	Growing gap between spending and user-based revenues Search for alternative revenue streams (e.g., tolls, mileage based fees, value capture, etc.)	▪ Acceptable revenue sources ▪ Role of federal government ▪ Impact of sharing economy	➢ Decreased public funding for transportation projects ➢ Adverse impact on the economy ➢ Growing private role, more complex governance ➢ User-pays economy ➢ Equity issues
	Freight e-commerce, globalization	Growing e-commerce/same-day delivery market Testing/deployment of AV/EV/ICT for supply chain management and cost savings Dramatic increases in truck traffic	▪ Viability of STTF for freight projects ▪ Impact on congestion and maintenance ▪ Rate of AV adoption and infrastructure needs ▪ Impact of crowdsourcing technology ▪ Methods to accommodate deliveries for short distance shipments	➢ Decreased public funding for freight projects ➢ Growing demand leads to urban congestion and maintenance needs ➢ Deployment of AV/truck only lanes reduce delivery costs and improve safety ➢ First/mile last mile delivery innovations (UAVs, TNCs) ➢ Crowdsourcing of warehouse capacity
	Transportation Investment, Equity, and the Economy productivity, economic cycles, equity	Transportation impacts the economy and facilitates access to jobs and opportunities. Transit ridership declines as economy improves or as gas prices go down	▪ Impact of investments on economic productivity, access to opportunity ▪ Public response to increased transit investment ▪ Cost of transportation	➢ Transit investment fails to increase ridership in less dense areas or during economic growth ➢ Investments may or may not increase productivity ➢ Cost of transportation influences housing location ➢ Lack of affordable transportation options impedes access to opportunity

Appendix B
Transportation Asset Vulnerability

Table B- 1. Transportation Asset Vulnerability

Asset Categories	Assets	Risks								
		Technology				Natural Hazards/Climate				
		Automated and Connected Vehicles	Ridesourcing and Ridesharing	Alternative fuels and Zero Emission Vehicles	Hyperloop	Sea level rise	Extreme temperature	Increased precipitation and flooding	Wildfires	Extreme weather events
Highway	Pavement	◑	○	○	○	◑	●	●	●	●
	Interchanges and intersections	●	○	○	○	◑	○	◑	◑	●
	Corridors	●	○	○	◑	◑	○	●	●	●
Structure	Bridges and tunnels	●	○	○	○	●	●	●	●	●
	Culverts	◑	○	○	○	●	○	●	○	●
	Mechanically stabilized earth (MSE) retaining walls	◑	○	○	○	●	○	●	○	●
	Ditches	○	○	○	○	●	○	●	○	●
	Catch basins	○	○	○	○	●	○	●	○	●
	Under/edge drains	○	○	○	○	●	○	●	○	●
Safety	Barriers, i.e. Guard rails	○	○	○	○	○	○	◑	○	●
	Signals	◑	○	○	○	○	○	○	◑	●
	Signs	◑	○	○	○	○	○	○	◑	●
	Pavement markings	●	○	○	○	○	○	○	○	○
Multimodal	Railway yards and stations	●	○	○	●	◑	○	◑	◑	●
	Ports	○	○	○	●	●	○	◑	○	●
	Bikeways, sidewalks, and trails	◑	◑	◑	○	◑	●	●	●	●
	Airports	○	○	○	●	◑	●	●	◑	●
	Intermodal facilities	◑	○	◑	◑	◑	●	●	○	●
	Weighing stations	◑	○	○	◑	○	○	○	○	●
Vehicle	Transit fleet	●	●	●	◑	○	○	◑	◑	●
	Incident Response Vehicles (IRV)	○	○	○	○	●	●	●	●	●
Technology	Traffic management centers	●	○	○	○	○	○	○	○	●
	Intelligent Transportation Systems (ITS)	●	○	○	○	○	○	○	○	●
Real Estate	Right-of-Way	●	○	○	●	○	○	●	●	●
	Government-owned land	◑	○	○	◑	◑	○	●	●	●
	Rest areas and welcome centers	◑	○	○	○	○	○	●	●	●

Not vulnerable	○
Somewhat vulnerable	◑
Highly vulnerable	●

Appendix C
Risk Treatment Plans

Table C- 1. Rating Consequences

	Descriptor	Health & Safety	Image / Reputation	Environment	Stakeholder Interest	Cost	Time	Rating
Threat	**Substantial**	Multiple fatalities	International Media Cover	Permanent widespread ecological damage	Commission of Inquiry	+$10M	Many years	**100**
	Major	Several fatalities	Sustained National Media Cover	Heavy ecological damage, costly restoration	Ministerial Inquiry	+ $1M to $10M	Years	**70**
	Medium	Serious Injuries	Regional Media Cover or Short Term National Cover	Major but recoverable ecological damage	Ministerial Questions or 3rd party investigation	+ $100k to $1M	Months	**40**
	Minor	Minor Injuries	Local Media Cover	Limited but medium-term negative effects	Official Information Request	+ $10k to $100k	Weeks	**10**
	Negligible	Slight Injuries	Brief Local Media Cover	Short-term damage	Minor Complaint	+ $0 to $10k	Days	**1**
Opportunity	**Negligible**	Prevention of Slight Injuries	Brief Local Media Cover	Short-term enhancement	Letter of support	- $0 to $10k	Days	**-1**
	Minor	Prevention of Minor Injuries	Local Media Cover	Limited but medium-term enhancement	Submission in support for RMA and LTMA	- $10k to $100k	Weeks	**-10**
	Medium	Prevention of Serious Injuries	Regional Media Cover or Short Term National Cover	Medium to long term ecological enhancement	Champions in community	- $100k to $1M	Months	**-40**
	Major	Saving of Several fatalities	Sustained National Media Cover	Long Term and important ecological enhancement	Small financial contribution	- $1M to $10M	Years	**-70**
	Substantial	Saving of Multiple fatalities	International Media Cover	Permanent widespread ecological enhancement	Large financial contribution	-$10M	Many Years	**-100**

Source: Transit New Zealand, 2004

Table C- 2. Sample Risk Treatment Plan

Activity	
Contract No.	
Date	

Analysts Name(s)	
Reviewers Name(s)	
Sources of Information	

No.	Name	Threat or Opportunity	Treatment Type	Treatment Progress	Treatment Actions	Responsibility	Timing	Resources	Monitoring & Reporting	Treatment Cost	Risk Reduction
1	Unforeseen ground conditions under piles	Threat	Minimise	Completed	1.1 Complete additional logged bores at every second pile location	F Dagg	by 30 Mar'04	3 days work for 1 boring rig from XYZ-Testing Ltd.		**15,000**	n/a
				Commenced	1.2 Reassess piling systems adequacy in consideration of 1.1 above	A B Cee	Meeting to agree design change on 30 Jun'04		Design review & brief report prepared by consultant where necessary	**5,000**	Likelihood of insufficient bearing capacity reduced by 50%, but with possible increased piling base cost. Target net. saving of $300,000

The type of approach that will be taken in treating the risk. This may be: A. Accept / P. Accept / Transfer / Maximise / Enhance / Avoid / Minimise / Mitigate.

A brief indication of current progress on the treatment plan

A list of actions required to complete the treatment of a risk.

The individual(s) responsible for completing the treatment action.

Deadline for completion of treatment actions

A summary of the resources required to complete the treatment action.

The full cost of treatment (estimated or actual).

The estimated reduction in risk, at the expected level, following completion of the treatment.

Source: Transit New Zealand, 2004

Table C- 3. Threat Categories with Suggested Treatment Types

MITIGATE WHENEVER POSSIBLE

Likelihood	CONSEQUENCES (loss)				
	Negligible (1)	Minor (10)	Medium (40)	Major (70)	Substantial (100)
Likely (5)	5 Low threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Accept - Repair	50 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential	200 Very high threat AVOID - Immediate action - Enhance systems to minimise potential	350 Extreme threat AVOID Immediate action - Cease activity	500 Extreme threat AVOID - Immediate action - Cease activity
Quite Common (4)	4 Low threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Accept - Repair	40 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Insure	160 Very High threat AVOID - Immediate action - Enhance systems to minimise potential	280 Very high threat AVOID - Immediate action - Contingency Plans	400 Extreme threat AVOID - Immediate action - Cease activity
Unlikely (3)	3 Negligible threat ACCEPT PASSIVELY - Repair	30 Moderate threat ACCEPT ACTIVELY - Enhance systems to minimise potential - Insure - Contingency Plans	120 High threat ACCEPT ACTIVELY OR TRANSFER - Immediate action - Insure - Contingency Plans	210 Very high threat AVOID - Immediate action - Avoid - Contingency Plans	300 Very high threat AVOID - Immediate action - Avoid - Contingency Plans
Unusual (2)	2 Negligible threat ACCEPT PASSIVELY - Repair	20 Low threat ACCEPT ACTIVELY OR TRANSFER - Repair	80 High threat ACCEPT ACTIVELY OR TRANSFER - Monitor - Insure - Contingency Plans	140 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans	200 Very high threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans
Rare (1)	1 Negligible threat ACCEPT PASSIVELY - Repair	10 Low threat ACCEPT ACTIVELY OR TRANSFER - Repair	40 Moderate threat ACCEPT ACTIVELY OR TRANSFER - Monitor - Insure - Contingency Plans	70 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans	100 High threat AVOID OR TRANSFER - Monitor - Insure - Contingency & Disaster Plans

MINIMISE WHENEVER POSSIBLE

Source: Transit New Zealand, 2004

Appendix D
FTP Risk Register

Table D- 1. FTP Risk Register

	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
Goal 1: Safety and security for residents, visitors, and businesses	**Threats**							
	Hacking and cybersecurity threats to public and private transportation	4	4	5	80	E	Extreme Risk	Avoid
	New technology causes investment to be prematurely obsolete	4	4	5	80	E	Extreme Risk	Avoid
	Intensification of development in high hazard areas	5	4	4	80	C	Extreme Risk	Avoid
	Aging population causes surge in demand for safe mobility options	5	4	3	60	E	High Risk	Coordinate
	Wildfires disrupt major transportation routes and reduce visibility	4	3	4	48	U	Moderate Risk	Mitigate
	New technology systems perform unsafely or increase liability	3	5	3	45	U	Moderate Risk	Avoid
	Failure to evacuate vulnerable populations due to evacuation routes in high hazard areas	2	5	4	40	U	Moderate Risk	Coordinate
	Arterial flooding disrupts major transportation routes and systems	4	3	3	36	C	Moderate Risk	Mitigate
	Opportunities							
	Decrease in incidents caused by unsafe, distracted, and impaired driver and operator behavior							Enhance
	AV offers safe mobility for aging population, teenagers, and users with limited mobility							Share
	Enhanced real time data collection and reporting for safety, security incidents, and exposure							Enhance
	Improved travel safety and decrease in intersection crashes							Enhance
	Safer and more secure freight movement							Share
	AV/CV /ICT facilitates real time communication, emergency response and recovery							Exploit
	Improved safety and security of airspace due to technological advancements							Share
	Blockchain strengthens digital security							Exploit
	ICT improves transportation connectivity to military facilities							Share

Goal 2: Agile, resilient, and quality transportation infrastructure	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Inadequate funding for high-tech infrastructure and services	5	4	5	100	E	Critical	Coordinate
	Infrastructure expansion in high hazard areas	5	4	5	100	C	Critical	Avoid
	High maintenance costs of new technology and materials	4	4	5	80	E	Extreme Risk	Avoid & Coordinate
	Damage to infrastructure from extreme weather events	4	5	4	80	C	Extreme Risk	Mitigate
	New technology causes investment to be prematurely obsolete	4	4	5	80	E	Extreme Risk	Avoid
	Inadequate network redundancy or reliever routes	5	4	4	80	C	Extreme Risk	Coordinate
	Flooding degrades drainage structures and pavement	5	3	5	75	C	Extreme Risk	Mitigate
	Short term power outages disrupt CV/ICT systems	4	4	4	64	C	High Risk	Mitigate
	Few corridors that provide separate AV and/or freight lanes	4	4	4	64	N	High Risk	Avoid
	Hacking and cybersecurity threats to public and private transportation	3	4	5	60	N	High Risk	Mitigate
	Energy shortages or long term power outages disrupt CV/ICT systems	3	5	4	60	N	High Risk	Mitigate
	Reduced pavement life due to high temperatures	4	3	3	36	C	Moderate Risk	Avoid
	Reduced pavement life due to commercial AV fleets	4	3	3	36	N	Moderate Risk	Avoid
	Too much excess transportation system capacity	3	2	1	6	N	Low Risk	Avoid
	Opportunities							
	Public/private partnerships and growth of entrepreneurial services							Share
	ICT allows more resilient infrastructure design, construction, maintenance, and operation							Exploit
	Improved availability of infrastructure data across modes and levels of government							Exploit & Share
	Technology facilitates integrated corridor management (ICM) and multimodal integration							Exploit & Share
	AV/CV increases arterial capacity							Exploit
	CV applications provide information on infrastructure health or condition							Exploit & Share
	3D printing reduces production and construction costs							Exploit

Goal 3: Efficient and reliable mobility for people and freight	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Inadequate funding for design and construction of multimodal high-tech corridors	5	4	5	100	E	Critical	Avoid
	Failure of AV/CV to improve efficiency of travel and freight due to mixed traffic	4	4	5	80	E	Extreme Risk	Mitigate
	New technology causes investment to be prematurely obsolete	4	4	5	80	E	Extreme Risk	Avoid
	Continued urban sprawl and auto-dependent development	5	4	4	80	E	Extreme Risk	Transfer & Coordinate
	Increase in travel delays and cancellations	4	4	4	64	C	High Risk	Mitigate
	System hardware and software failure	3	4	4	48	N	Moderate Risk	Mitigate
	Major disruptions in freight traffic due to extreme weather	3	4	4	48	C	Moderate Risk	Mitigate
	Limited system connectivity due to poorly coordinated agency deployment timelines or inconsistent technologies	3	4	4	48	N	Moderate Risk	Coordinate
	Inability to enact appropriate regulations related to technology	3	3	3	27	C	Moderate Risk	Coordinate
	Rapid expansion of e-commerce and same day delivery exceeds capacity	3	3	2	18	E	Low Risk	Avoid
	Inadequate EV charging infrastructure to meet demand	4	2	2	16	C	Low Risk	Transfer
	Opportunities							
	Ability to dynamically shift travelers to other routes or modes using real time information							Enhance
	Increased connectivity for a more efficient and reliable system							Enhance
	More mobility options for aging population, teenagers, and users with limited mobility							Enhance & Share
	Ridesourcing and ridesharing services improve first and last mile connectivity							Share
	Improved payment systems across transportation modes and jurisdictional boundaries							Enhance & Share
	Improved supply chain, such as real-time load matching, crowdsourcing of warehouse capacity							Share
	Improved system capacity and operations							Exploit
	Ability to accommodate increased density and mix of uses							Share

Goal 4: More transportation choices for people and freight	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Lack of public acceptance of proposed projects	5	5	4	100	C	Critical	Mitigate
	Inadequate funding and economic downturns restrict ability to expand travel options	5	4	4	80	E	Extreme Risk	Mitigate & Coordinate
	Increased urban sprawl and auto-dependent development	5	5	3	75		Extreme Risk	Coordinate & Transfer
	Limited system connectivity due to poorly coordinated agency deployment timelines	4	4	4	64	N	High Risk	Coordinate
	Increased travel demand due to population growth	5	3	3	45	C	Moderate Risk	Mitigate & Coordinate
	Transit investment fails to increase or attract sufficient ridership	4	3	3	36	C	Moderate Risk	Mitigate
	Inequity of AV applications for growing disadvantaged population	3	3	3	27	N	Moderate Risk	Coordinate & Transfer
	Societal shifts in transportation preferences and needs in light of changing technology	4	2	3	24	E	Low Risk	Mitigate
	Inadequate EV charging infrastructure	4	2	2	16	C	Low Risk	Coordinate & Transfer
	Opportunities							
	Improved first and last mile connectivity by ridesourcing and ridesharing services							Share
	Ease of integrated corridor management (ICM) and multimodal integration							Exploit & Share
	More mobility options for aging population, teenagers, and users with limited mobility							Enhance & Share
	Improved public information (or public awareness) across different modes of transportation							Enhance & Share
	Ability to accommodate increase density and mix of uses							Exploit & Share
	Improved public transportation services in rural areas and between rural and urban areas							Exploit & Share
	Expanded interregional travel options for residents, visitors, and freight							Enhance
	Reduced travel demand due to e-commerce, telecommunications and telecommuting							Exploit
	UAVs reduce freight costs through the use of last-mile delivery services							Share

Goal 5: Transportation solutions that support Florida's global economic competitiveness	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Budget shortfalls restrict development and implementation of freight projects	5	3	4	60	E	High Risk	Coordinate
	Rising costs of fuels, equipment, materials, and construction	5	3	4	60	C	High Risk	Avoid
	Major disruptions in freight traffic due to extreme weather	5	3	4	60	C	High Risk	Mitigate & Transfer
	Decline in tourism or population	3	4	4	48	U	Moderate Risk	Mitigate
	Terrorism and cybersecurity threats	3	4	4	48	C	Moderate Risk	Mitigate
	Inadequately trained and aging workforce	5	3	3	45	C	Moderate Risk	Avoid
	Escalation of transportation costs	4	3	3	36	C	Moderate Risk	Coordinate
	Reduced freight and tourist activity negatively impacts state revenue	2	4	4	32	U	Moderate Risk	Avoid
	Job losses or shifts to other occupations as a result of automation	4	3	2	24	E	Low Risk	Transfer
	Flight delays or cancellations	5	2	2	20	C	Low Risk	Transfer
	Opportunities							
	Reduced freight costs as a result of AV and freight supportive infrastructure							Exploit
	Enhanced real time data collection for supply and demand							Enhance
	Multimodal integration to support tourism							Enhance
	AV/CV/ICT improves connectivity of areas, facilities, and systems							Exploit
	Shorter commute and travel times for residents and visitors							Enhance
	Improved ability to attract skilled workforce							Enhance & Share

Goal 6: Transportation solutions that support quality places to live, learn, work, and play	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Funding constraints impede ability to provide design amenities	5	4	4	80	E	Extreme Risk	Mitigate & Coordinate
	Inequitable AV applications for low income populations	4	3	4	48	N	Moderate Risk	Avoid & Transfer
	Investments fail to provide access to opportunity	3	4	4	48	U	Moderate Risk	Avoid
	Growth in freight delivery and movement adversely impacts livability in urban centers	3	4	4	48	E	Moderate Risk	Avoid & Coordinate
	Increased urban sprawl and auto-dependent development patterns	4	3	3	36	C	Moderate Risk	Coordinate
	TNCs and AVs increase need for curb space management	5	2	3	30	E	Moderate Risk	Coordinate
	Opportunities							
	MaaS and Smart Cities dramatically expand travel options and multimodal integration							Enhance & Share
	Alternative fuels and zero emission vehicles improve air quality in urban areas							Enhance
	AV/Maas creates opportunities to repurpose existing right-of-way for complete streets							Exploit
	Improved data on community values, mode usage, and transportation preferences							Exploit
	AVs could reduce need for urban parking, allowing more compact development							Share
	Higher density, mixed-use core areas support more diversity of modes							Share
	Increasing preference for walkable and bikeable communities							Enhance

Goal 7: Transportation solutions that support Florida's environment and conserve energy	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Timeframe	Risk Level	Consequence Management
	Threats							
	Failure to reduce emissions that adversely impact climate and health	4	5	5	100	C	Critical	Avoid
	Increased urban sprawl and auto-dependent development patterns	5	3	5	75	C	Extreme Risk	Transfer
	New corridors disrupt sensitive ecosystems and wildlife corridors	4	4	4	64	C	High Risk	Avoid
	Cheap gas impedes adoption of ZEV and clean fuels and reinforces sprawl	3	4	5	60	C	High Risk	Mitigate
	AV induces demand for longer or more frequent SOV trips	4	4	3	48	N	Moderate Risk	Mitigate
	Opportunities							
	Improved air quality in urban areas as a result of EVs and alternative fuels							Enhance
	Improved fuel efficiency through the use of platooning techniques and truck only lanes							Exploit
	Cleaner fuels and energy efficient practices in freight operations and manufacturing							Share
	AV/CV/ICT reduces hazards to wildlife							Exploit
	Increasing preference for walkable and bikeable communities							Enhance

Appendix E
FTP Alternative future Screening Results

Below is a summary of risk robustness for threats, opportunities, and total risk robustness scores for all alternative futures by goal (Table E- 1). This information summarizes the totals for each of 35 alternative future screening matrices.

Table E- 1. Summary of Alternative future Screening Risk Robustness Results

Goals	Risk Events	Risk Robustness By Alternative future				
		Return to Historic Growth	Rural Rediscovery	Innovation Hub	Global Trade Hub	Risks on the Horizon
Safety	Threats	67%	66%	54%	68%	67%
	Opportunities	64%	65%	92%	63%	69%
	Total	65%	65%	74%	65%	68%
Infrastructure	Threats	57%	50%	57%	60%	78%
	Opportunities	76%	77%	85%	71%	57%
	Total	64%	60%	67%	64%	70%
Mobility	Threats	62%	64%	50%	65%	88%
	Opportunities	78%	70%	84%	81%	47%
	Total	68%	67%	64%	72%	71%
Choices	Threats	60%	62%	53%	64%	71%
	Opportunities	64%	68%	92%	65%	68%
	Total	62%	65%	72%	65%	69%
Economy	Threats	66%	51%	50%	63%	60%
	Opportunities	81%	83%	90%	77%	81%
	Total	72%	63%	65%	68%	68%
Quality Places	Threats	70%	65%	60%	81%	74%
	Opportunities	71%	76%	90%	53%	76%
	Total	71%	71%	76%	66%	75%
Environment	Threats	67%	65%	53%	71%	52%
	Opportunities	69%	67%	70%	68%	98%
	Total	68%	66%	62%	69%	75%

Total Robustness

The total robustness score combines the rankings for threats and opportunities. Total robustness gives a sense of how well the alternative future/goal combination perform when all risk events are considered together. The scores are summarized in Table E- 2. As can be seen, total risk robustness scores range from a low of 60% to a high of 76%. Although this suggests some meaningful differences among the futures in terms of overall robustness, the variation across futures is not wide. This is in contrast to much greater variation in scores (from 47% to 98%) when threats and opportunities are not combined for a total score. Recall that a high

robustness score for threats means that alternative future is not susceptible to threats and that a high opportunity score means an alternative future is well positioned for opportunities.

Interestingly, the total robustness scores can obscure very different threat and opportunity risk robustness. It is therefore important to note that, although "total risk robustness" combines the threat and opportunity scores to provide insight into the overall resiliency of the alternative future, the opportunity and threat scores should also be considered.

For example, the *Return to Historic Growth* future for the Quality Places goal has a total robustness score of 71%, reflecting the average of a 70% threat score and a 71% opportunity score. By contrast, the *Risks on the Horizon* future for the Mobility goal also has a 71% total robustness score—but this reflects an 88% threat score and 47% opportunity score. The former 71% case (*Return to Historic Growth*, Quality Places) is generally stronger since the total score reflects robustness for both opportunity and threats, whereas the latter 71% case (*Risks on the Horizon*, Mobility) offers limited opportunity and would be applicable only where planning circumstances *require* high avoidance of threats.

Table E- 2. Total Risk Robustness

	Return to Historic Growth	Rural Rediscovery	Innovation Hub	Global Trade Hub	Risks on the Horizon
Safety	65%	65%	74%	65%	68%
Infrastructure	64%	60%	67%	64%	70%
Mobility	68%	67%	64%	72%	71%
Choices	62%	65%	72%	65%	69%
Economic	72%	63%	65%	68%	68%
Quality Places	71%	71%	76%	66%	75%
Environment	68%	66%	62%	69%	75%

Looking into the results, the data reveal how specific alternative future /goal combinations perform.

Highest total alternative future robustness percentage

76%, Innovation Hub alternative future, Quality Places goal

Of all possible alternative future and goal rankings, the *Innovation Hub* alternative future under the Quality Places goal is the highest scoring for total robustness percentage. This is the most optimal situation investigated, where threats are limited and opportunities are abundant.

Lowest total alternative future robustness percentage

60%, Rural Rediscovery alternative future, Infrastructure Goal

Of all possible alternative future and goal rankings, the *Rural Rediscovery* alternative future under the Infrastructure goal is the lowest scoring for total robustness percentage. This is the least optimal situation investigated, where threats are high and opportunities are limited.

Of all the alternative future/goal combinations, the *Innovation Hub* for Quality Places goal is the most compelling in terms of minimal threats and high opportunities. The *Innovation Hub* alternative future also scores very high for total alternative future robustness for safety (74%) and choices (72%) goals, and generally does well across all other measures. **These findings suggest that the *Innovation Hub* alternative future is an alternative future that offers FDOT a desirable platform for future transportation planning**—whether the agency works proactively to shape transportation planning to support this future or if the agency must be responsive to trends indicating this future for Florida.

On the contrary, the alternative future/goal combination of *Rural Rediscovery* for the Infrastructure goal ranks lowest for total alternative future robustness. Total alternative future robustness for all but one of the *Rural Rediscovery* goals was below 70%. Likewise, threats across most goals for *Rural Rediscovery* are low, suggesting an alternative future that will present high susceptibility to threats and therefore significant challenges for future transportation planning in Florida. Overall, *Rural Rediscovery* does not appear to be a future with desirable planning implications. However, the *Rural Rediscovery* alternative future is not all problematic, and scores well when just opportunity robustness is examined for some goals.