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Evaluation and Enhancement of the Florida Statewide Model

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Forecasting and Trends Office

Florida Department of Transportation

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DISCLAIMER

METRIC CONVERSION CHART

APPROXIMATE CONVERSIONS TO SI UNITS

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
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
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 1000 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)				
°F	Fahrenheit	5 (F−32)/9 or (F−32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	pound force	4.45	newton	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or t)	mega grams (or metric ton)	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newton	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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16. Abstract

This project developed a roadmap for future model enhancements of the Florida Statewide Model (FLSWM) in light of emerging planning issues and proposed enhancement strategies incorporating advanced demand modeling techniques. The roadmap was developed with accomplishment of three tasks: literature review, model evaluation with scenario analysis, and identification of improvement needs.

The roadmap encompasses improvement tasks grouped into short-term, mid/long-term, and long-term stages. In the short-term, the trip-based approach of existing FLSWM is maintained. Modifications should focus on the most urgent needs, including time-of-day factoring that split daily trip tables into multiple periods which enables traffic assignment of peak periods. Additional modification could consider expanding the capacity of the cross-classification model for trip generation by including additional stratifications such as area type or household income. In the mid/long-term, a transition to an activity-based model can be staged given resources available. Through a population synthesizer, which simulates a population with detailed characteristics based on U.S. Census data, a variety of variables can be included in the subsequent choice models. A mobility choice component would be needed to address the adoption of vehicle technologies and mobility services, which would be critical in the era of autonomous, connected, electric shared vehicles (ACES). In addition, dynamic traffic assignment or traffic microsimulation can produce hour-by-hour traffic volumes that can effectively facilitate evaluation of efficiency-oriented policies and technologies. Longer-term enhancement may consider location choices for home, work and school and reflect the connection between transportation accessibility and land use. An additional mobility choice component, such as telecommuting adoption, can also be beneficial and reflect potential trend in telecommunications and the impacts on travel demand.

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EXECUTIVE SUMMARY

Statewide travel demand models are essential tools to support planning and programming activities at the state and regional level. The current Florida Statewide Model (FLSWM) follows the conventional four-step travel demand modeling approach. Emerging issues such as evaluating traveler responses to congestion and pricing, multimodal transportation planning and operations, social and economic impacts, and incorporating emerging technologies and mobility services cannot be effectively evaluated with FLSWM due to model limitations in behavioral, spatial, and temporal resolution.

The goal of this research is to provide a roadmap for improvements and enhancements of the passenger travel model in the current Florida Statewide Model (FLSWM) to address emerging policy and planning issues. Four specific tasks were executed for achievement of the goal:

1. Comprehensive literature review of statewide travel demand modeling practice
2. Evaluation of existing FLSWM capabilities
3. Identification of model improvement needs
4. Recommendations for improvements by stages.

The review of literature began with identification of planning applications and issues of statewide travel demand modeling, followed by an introduction of structures and components of existing statewide models. It was found that currently 40 states have developed statewide models. Statewide models were mostly used by state governments to evaluate transportation policies and investments decisions involving both passenger and freight travel activities across vast geographical boundaries, such as intercity and interstate, not covered by urban travel demand models used by Metropolitan Planning Organizations (MPOs). Two basic modeling structures have been used for statewide passenger models: trip-based and activity-based models. A statewide model typically consists of a passenger travel component and a freight traffic component. Some statewide models produce long distance intra- and interstate trips in addition to short distance urban trips. Model components specifically designed to predict visitor trips exist in some statewide models. Some states have adopted new data and modeling techniques to improve model capabilities. Origin-destination matrices derived from cellphone data have been used by several states for calibration of statewide trip tables. A national long-distance travel model derived from existing long distance travel survey data has been integrated with the statewide model of Tennessee for prediction of long-distance trips. Incorporation of commercial geographical information systems data for development of modeling networks has also gained popularity among modelers working on statewide models.

Evaluation of FLSWM's passenger model was achieved by running the model for scenarios that were devised to assess the performance of the model and to demonstrate potential applications of the model. The scenarios focused on long distance travel, transportation planning in rural counties, and evaluation of traffic impacts from adoption of automated, connected, electric, and shared-Use (ACES) vehicles. Analysis of scenarios with long distance business (LDB) trips

showed that LDB trip distribution friction factors with the upper travel time limit of 180 minutes do not correctly reflect the geographic coverage of Florida. Recalibration of LDB gravity model friction factors with upper limit longer than 180 minutes or replacing the LDB gravity model with a destination choice model needs to be considered in the next FLSWM update. Installation of a visitor model in FLSWM also needs to be considered for the large number of visitors who visit Florida every year. For highway projects in rural counties not covered by MPO or regional travel demand models, FLSWM can be used to evaluate the traffic impacts of such projects. However, if peak hour traffic is the concern for these highway projects, FLSWM's prediction of daily traffic volumes needs to be post-processed with appropriate peak hour factors. The traffic impacts from various scenarios of ACES adoption can be evaluated with FLSWM through assumptions of network capacities and percent increase in automobile trips by ACES vehicles. Editing a large number of network links and attributes can be difficult due to lack of dedicated user interfaces.

To identify current and emerging planning and policy issues in Florida to be addressed by the FLSWM, documents produced for the latest Florida Transportation Plan (FTP) update were reviewed. With the review, we identified specific modeling capabilities that are required for FLSWM to address planning issues identified in FTP. The most pressing need for FLSWM improvement is to recalibrate the LDB trip distribution model. The visitor model of FLSWM also needs to be updated with new data. By producing a loaded network with 24-hour traffic volumes, FLSWM is limited in its effectiveness for evaluating projects that deal with congestion relief or emission reduction. Transition to an activity-based approach may be necessary to fully address the impacts of shifting demographics, changing travel behavior, and potential implications of ACES.

Depending on the complexity of the improvements and the associated data and resources needed, the recommendations are grouped into short-term, mid/long-term, and long-term stages. In the short-term, the trip-based approach will be maintained. Modifications should focus on the most urgent needs, including time-of-day factoring that splits daily trip tables into multiple periods, which enables traffic assignment of peak periods. Additional modification could consider expanding the capacity of the cross-classification model for trip generation by including additional stratifications such as area type or household income. In the mid/long-term, transition to an activity-based model can be staged with available resources. Through a population synthesizer, which simulates a population with detailed characteristics based on U.S. Census data, a variety of variables can be included in the subsequent choice models. A mobility choice component would be needed to address the adoption of vehicle technologies and mobility services, which would be critical in the era of ACES. In addition, dynamic traffic assignment or traffic microsimulation can produce hour-by-hour traffic volumes that can effectively facilitate evaluation of efficiency-oriented policies and technologies. Longer-term enhancement may consider location choices for home, work, and school and reflect the connection between transportation accessibility and land use. An additional mobility choice component, such as telecommuting adoption, can also be beneficial and reflect potential trend in telecommunications and the impacts on travel demand.

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1 INTRODUCTION

Statewide travel demand models are essential tools to support planning and programming activities at the state and regional level. Statewide modeling is used to help formulate transportation plans and policies, evaluate and prioritize projects and programs, and assess the economic and social impacts of major transportation investments. The Florida Statewide Model (FLSWM) is such a tool that provides travel demand analysis to inform a wide variety of policy, planning, and investment decisions as well as programming activities at the state and regional level. It also provides critical information (such as external demand, freight flows, etc.) to regional models. Developing statewide models has been recognized as a challenging task, as they often "address a wider range of requirements, cover much larger areas, and focus on markets that are not as well understood as those in urban areas" (NASEM, 2017).

With continuously growing population and rapidly evolving technologies, Florida is facing several transportation planning and policy issues that cannot be fully addressed by the current FLSWM due to the simplified and aggregated nature of the traditional four-step approach. Emerging issues such as evaluating traveler responses to congestion and pricing, multimodal transportation planning and operations, social and economic impacts, and incorporating emerging technologies and mobility services require modeling travel demand with high levels of behavioral, spatial, and temporal resolution.

Recognizing the limitations of the traditional four-step models, many states are moving toward advanced methods, either through incorporation of advanced features that significantly enhance model capabilities or by adopting an activity-based model (ABM) approach. With the ability to reflect individual choice settings, ABMs are much more responsive to modern transportation policies oriented toward management vs. capacity expansion.

Given the above discussions, this project developed a roadmap for future model enhancements of the FLSWM in light of emerging planning issues and propose enhancement strategies incorporating advanced demand modeling techniques. The specific objectives include:

1. Identify current and emerging planning and policy issues in Florida to be addressed by FLSWM;
2. Evaluate the performance and capability of the existing FLSWM according to the state of the practice and the state of the art in statewide modeling;
3. Recommend incremental enhancement strategies considering analysis needs, data availability, and cost for model development and implementation.

Enhancing FLSWM and equipping Florida decision makers with a better tool to address a broad range of issues in the state will lead to a more effective transportation system that enhances mobility, supports economic development, and promotes sustainable growth in Florida. This study will provide recommendations for model enhancements in the next five years. It will provide a consistent and systematic framework for model development and enhancements to meet the planning and policy analysis needs in the state. A roadmap for future enhancements will lead to more cohesive model development activities and avoid duplicating or conflicting efforts.

This report is organized as follows. The next chapter presents a comprehensive review of literature relevant to current statewide travel demand modeling practices, followed by an overview of model structure and evaluation of the existing FLSWM. Chapter four presents a needs assessment of the FLSWM considering the planning needs in the state of Florida. The last chapter summarizes recommendations for the future enhancements of the FLSWM in the short, mid, and long-term.

2. LITERATURE REVIEW

In 2017, the National Cooperative Highway Research Program (NCHRP) produced a synthesis (i.e., NCHRP Synthesis 514) of current statewide travel demand modeling practices in the United States (NASEM, 2017). The synthesis was intended to be used as a resource by transportation planners interested in developing and/or improving statewide travel demand models. Based on the references cited in NCHRP Synthesis 514, we conducted a comprehensive literature review to summarize current practices in statewide modeling, capture latest advances in the field, and identify exemplary practices and challenges. The review also summarized applications of statewide models that address emerging transportation issues and polices.

The review begins with identification of planning applications and issues of statewide travel demand modeling, followed by an introduction of structures and components of existing statewide models. We then provide a summary of current status of statewide modeling. Exemplary practices are then presented, followed by generalization of limitations in existing models and emerging methods that offer opportunities to addressing the limitations.

2.1 Statewide Travel Demand Models

Statewide travel demand models are developed for planning applications that address the impacts of transportation infrastructure investment and policy initiatives by state governments (NASEM, 2017). The practice of statewide travel demand modeling began gaining support from state governments with the advent of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which legislated formal requirements for collaborative intermodal transportation planning at various government levels (Giaimo and Schiffer, 2005). Since then, the number of states adopting statewide travel models have increased with improved modeling techniques and data availability. Currently, 40 states developed statewide models (IDOT, 2019), compared with 19 states identified in a survey in 2006 (Horowitz, 2006). The increasing adoption of statewide models reflects the need for state governments to evaluate transportation policies and investments decisions involving both passenger and freight travel activities across vast geographical boundaries, such as intercity and interstate, not covered by urban travel demand models used by Metropolitan Planning Organizations (MPOs).

2.2 Planning Applications of Statewide Travel Demand Models

In general, statewide travel demand models differ from MPO models in their wider spatial coverages and emphasis on freight transportation activities (NASEM, 2017). Travel activities between MPO boundaries and/or across state boundaries are not typically captured in MPO models. Statewide models are designed to specifically address these long-distance trips. For example, some routes not covered within MPO boundaries may carry significant amount of traffic that are vital to a state's economic development. With statewide models, the state departments of transportation (DOT) can evaluate investment proposals involving these routes.

Forecasting freight traffic is a major function in some statewide models for environmental impact assessment of statewide transportation plans because the amount of emissions from all the trucks on a state's highways can be very significant. Many statewide models include separate freight travel models to capture flows of freight trucks on state highways. Freights moving by rail, water, and air are also explicitly modeled with freight mode choice models in some statewide modeling applications.

Statewide travel demand models have been used for evaluations involving the following general categories of scenarios (NASEM, 2017):

- Infrastructure scenarios
- Policy scenarios
- Global scenarios

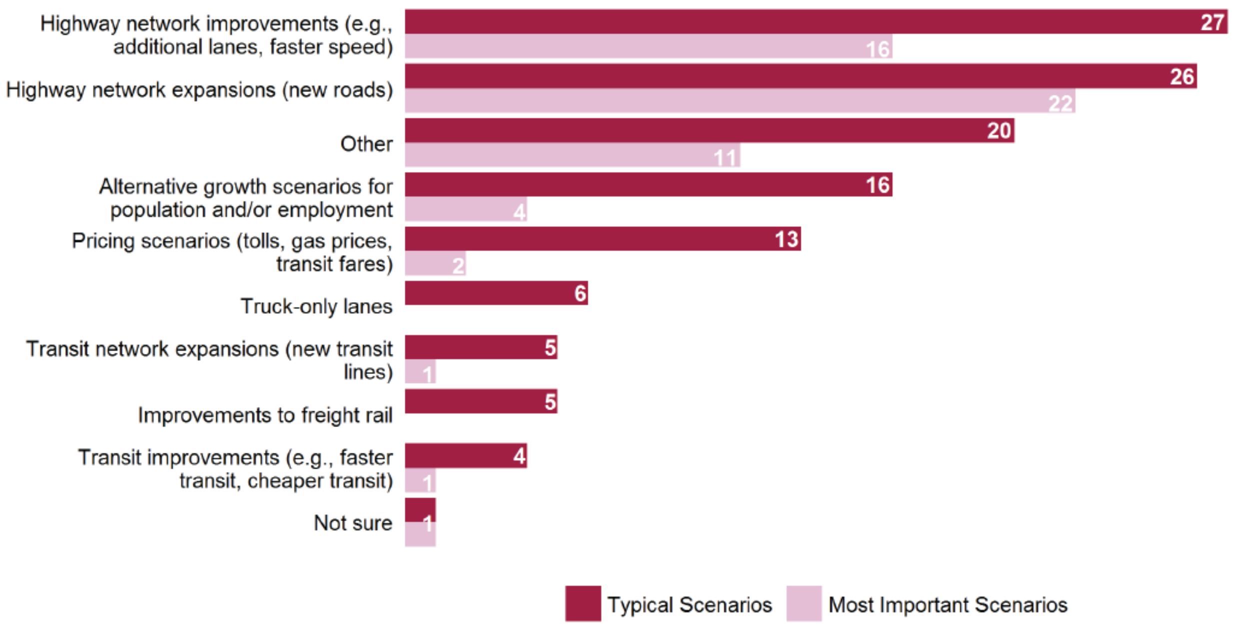
Statewide travel demand models are most often used to evaluate different infrastructural investment scenarios, such as new highways or transit lines, extension or improvement of existing facilities, and/or the development of major trip generators (e.g., housing or commercial projects) in specific locations that are expected to influence travel activities beyond spatial boundaries covered by MPO models. Such decisions may also involve abandoning existing facilities.

Policy scenarios refers to proposed policy measures intended to reduce travel demand and/or congestion, such as imposing tolls on a highway, designating truck routes, or increasing transit service. Policy scenarios may also involve other regulations actively implemented by a government that do not change the built environment.

Global scenarios refer to uncertain future developments, such as economic downturn, population and employment growth, energy price fluctuation, or widespread adoption of autonomous vehicles. Statewide travel models can be used to evaluate how these scenarios can impact a state's transportation systems, such as testing the range of gas price increase that are likely to see reduced congestion on freeways.

A formal survey was conducted for NCHRP Synthesis 514 (NASEM, 2017) to request information from state DOTs of all 50 states regarding statewide travel demand modeling practice. Figure 1 illustrates how statewide models have been used by DOTs to evaluate different scenarios.

The category labeled as "Other" are specific evaluation scenarios that are not listed in the survey forms but manually entered by survey respondents. These scenarios include road closure for highway construction and maintenance (Kentucky, Maine, Michigan, and Vermont); freight analysis (Texas and Utah); subarea analyses and select link analyses (Indiana and Nebraska); weight-restricted bridges, seismic impacts, and economic impacts of various levels of investment (Oregon); air quality conformity analysis (Massachusetts); and evacuation analyses (Florida).



(Source: NASEM, 2017)

Figure 1 Typical Scenarios Tested with Statewide Models

2.3 Planning Needs of Statewide Modeling

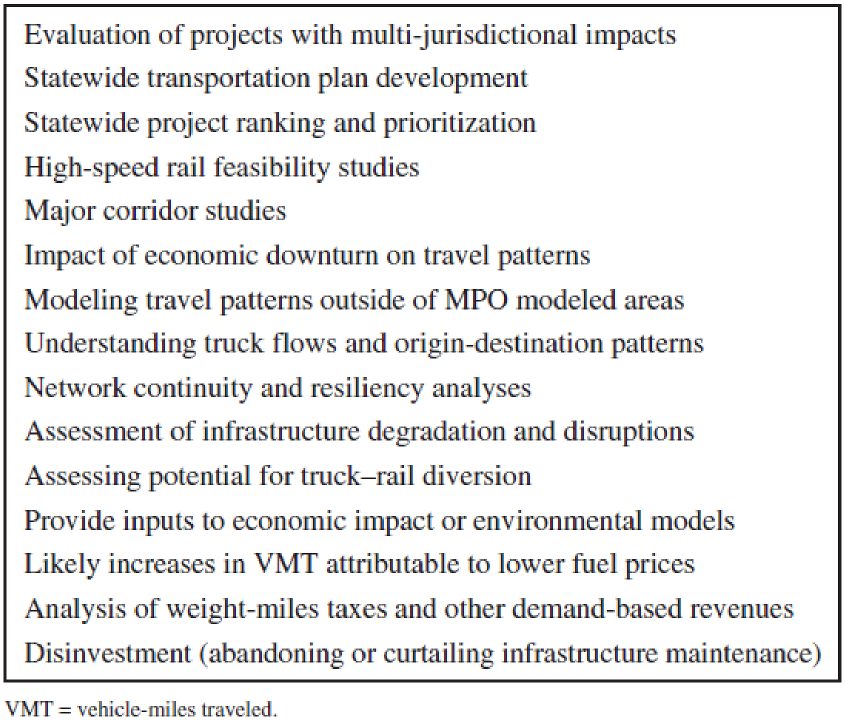
A separate survey was conducted in 2016 by the research team of NCHRP Synthesis 514 (NASEM, 2017), seeking responses from members and affiliates of TRB's statewide modeling subcommittee on issues related to statewide modeling practices. This survey was different from the aforementioned DOT survey in that contractors who developed and/or ran statewide models were also included. Three open-ended questions were posed to the interviewees (NASEM, 2017):

> "1. What are the most important analytical issues that you have recently used statewide models to evaluate? How suitable were the tools and data for the task? Did you encounter any noteworthy issues or challenges?
>
> 2. What emerging trends or issues have decision makers asked you for help evaluating, but for which your model was not up to the task for? In the same vein, what new questions do you expect to be hit with in the near future?
>
> 3. What data, methodological, and institutional barriers are holding statewide modeling back?"

Although only a limited number of responses were received (i.e., 11 responses received via emails and telephone interviews), the opinions from developers and users of statewide models are nevertheless illuminating with respects to the current state of statewide modeling and future directions for continuous development.

Table 1 lists the technical issues for which statewide models were used to evaluate. Evaluation of projects with multi-jurisdictional impacts was cited by most respondents, followed by statewide transportation plan development and prioritization. Most respondents indicated that their current models were suitable for obtaining solutions for the technical issues. However, some respondents cited lack of precision in the model for detailed corridor studies as the challenges for their current statewide models. A lack of data on visitors' travel patterns was also cited as a significant challenge for projects involving corridor studies. Inadequate resources dedicated to making the models user-friendly is another major challenge faced by some respondents. Specifically, coding modeling networks for various future development scenarios is very labor-intensive and time-consuming. This is a much more significant issue for larger states when statewide models are to be used for long range plan update that involves proposed improvements on all state highways.

Table 1 Frequently Cited Issues Studied with Statewide Models



Evaluation of projects with multi-jurisdictional impacts
Statewide transportation plan development
Statewide project ranking and prioritization
High-speed rail feasibility studies
Major corridor studies
Impact of economic downturn on travel patterns
Modeling travel patterns outside of MPO modeled areas
Understanding truck flows and origin-destination patterns
Network continuity and resiliency analyses
Assessment of infrastructure degradation and disruptions
Assessing potential for truck–rail diversion
Provide inputs to economic impact or environmental models
Likely increases in VMT attributable to lower fuel prices
Analysis of weight-miles taxes and other demand-based revenues
Disinvestment (abandoning or curtailing infrastructure maintenance)

VMT = vehicle-miles traveled.

(NASEM, 2017)

For the second question, respondents indicated that the most common emerging trends and issues involving statewide modeling include:

- Incorporation of big data
- Economic evaluation and cost-benefit analysis involving multimodal projects
- Forecasting the impacts of autonomous and connected vehicles on statewide transportation systems

Big data in the forms of cellphone-collected origin-destination matrices and travel times have the potentials to fill current gaps for much needed data, particularly for freight, long-distance passenger, and visitor travel activities. Regarding the rising trends and requirements of formal economic evaluations for large scale projects, some states use economic impact analysis models, such as TREDIS (EDRG, 2018), to process the results of statewide models for economic evaluation of projects. Integration of statewide models with an economic impact analysis model appears to be a long-term solution to this issue. The likely impacts of autonomous and connected vehicles will depend on how elements of the society (i.e., consumers, markets, and governments) respond to these new technologies (Isaac, 2016). Currently, no plan or action has been made regarding modeling the travel activities of connected and autonomous vehicles at any level of travel models.

For question 3, respondents cited several institutional and technical barriers for statewide modeling practices, including:

- Difficulty in attracting and retaining well qualified staff
- Lack of stable sources of funding for statewide modeling
- Difficulty of integrating statewide models with MPO models
- Lack of reliable data regarding regional or national travel activities affecting states

Almost all respondents reported that staffing issue, which is related to funding instability, was the biggest challenge for statewide modeling. It was noted that modeling staff are often hired at low pay grade, making it difficult for agencies to keep qualified modelers on staff. As a result, agencies often rely on consultants to develop, maintain and perform project evaluation with the models (NASEM, 2017).

Maintaining the same resolutions (e.g., TAZ size and time-of-day periods) of MPO models for an entire state presents significant challenges in terms of data requirements, development time, and computational burden. Many model developers chose to use aggregated data and representation for models at the statewide level (NASEM, 2017). A potential solution to increase consistency between MPO and statewide models is to use common data. For example, regardless of the size difference in the TAZs of the two models, if both models are calibrated to the same highway traffic data, analysis results of the two models can be consistent and complementary. Currently, suitable data on long-distance travel and visitor activities are difficulty to obtain (NASEM, 2017). It is expected that emerging new cellular technologies can offer data products for long-distance and visitor travel activities in the near future.

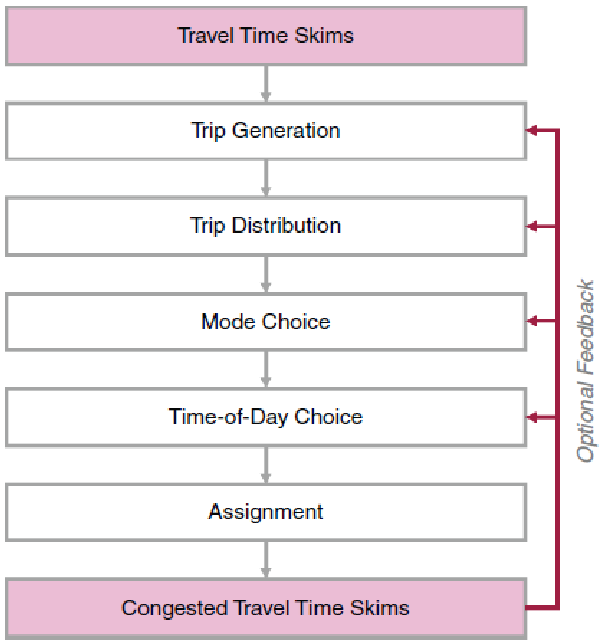
2.4 Structures and Components of Statewide Models

The methodologies for statewide models mostly derived from their predecessors, MPO models. Two basic modeling structures have been used for statewide models: trip-based and activity-based models. Trip-based models refer to models that built on the simplified assumption that individual travel for a particular purpose (e.g., work or non-work) between a pair of origin and destination without intermediate stops for other purposes. The movement between the origin and destination is termed a trip. Trip-based models follow four basic modeling steps: trip generation, trip distribution, mode choice, and traffic assignment. Models consisting these four steps are often referred to as four-step models. Activity-based models specifically consider the activities (e.g., daycare drop-off, work, lunch, daycare pick-up, shopping, and returning home) for which a travel is made (NASEM, 2017). The movement between the origin and destination is termed a tour, which can consist of multiple stops for various activities. Activity-based models have also been referred to as tour-based models.

2.4.1 Passenger Travel Models

The core of a travel demand model is the component that models travel activities of passengers by automobiles or transit. In a typical MPO model, passengers travel primary within the model region. For travel crossing the boundaries of the model area, external stations outside the MPO boundaries are used to represent the origins and/or destinations of these trips. For some statewide models, out-of-state passenger trips are modeled separately with a long-distance travel component.

In addition to the conventional four modeling steps, some trip-based models also include a time-of-day modeling process prior to traffic assignments to predict the numbers of auto or transit passengers traveling at different time periods of the day. For some states where highway traffic is the main focus of statewide travel modeling, the step of mode choice is skipped in the modeling process. Figure 2 shows the components of a typical trip-based statewide model.

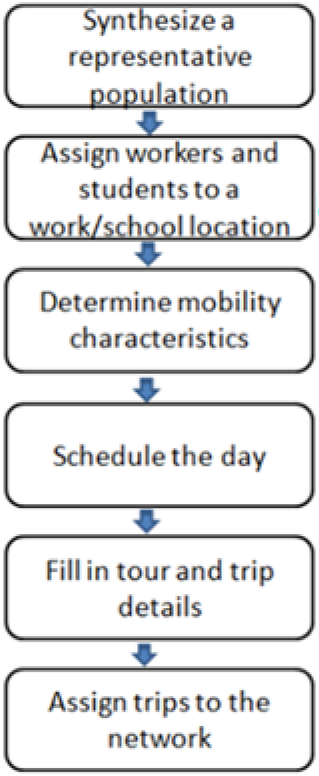


(Source: NASEM, 2017)

Figure 2 **Trip-Based Passenger Travel Modeling Process**

Activity-based modeling of passenger travel demand begins with the generation of synthetic population, work and school location assignment, and auto ownership prediction, followed by tour-formation, mode, destination, and time-of-day choice, and traffic assignment. Figure 3 shows a typical activity-based passenger travel modeling process.

Trip-based statewide models can usually be built with publicly available data such as travel behavior data from the National Household Travel Survey (NHTS) (BTS, 2020a), demographic and socioeconomic data from U.S. Census Bureau, and highway traffic data from state DOTs. Transferable rates of relevant travel behavior compiled in various NCHRP reports are also frequently used (Schiffer, 2012). Activity-based models are mostly built with data from household travel surveys conducted for the entire state. Three states (i.e., California, Ohio, and Oregon) with activity-based statewide models conducted statewide household travel surveys that provided a sample of data from households across the state (NASEM, 2017).



(SANDAG, 2020)

Figure 3 **Activity-Based Passenger Travel Modeling Process**

2.4.2 Long-Distance Passenger Travel Models

For states that explicitly model long-distance passenger travel, there is no consistent definition for a long-distance trip (NASEM, 2017). The definition in the 2001 NHTS for long-distance element of travel (i.e., trips greater than 50 miles) is used in most statewide models. Different sources of trip rates were used for trip generation of long-distance trips, such as trip rates provided in NCHRP Report 735 (Schiffer, 2012).

It is well recognized that there is a lack of available data for long-distance travel in the US (NASEM, 2017), making long-distance passenger trips difficult to model. Many existing long-distance passenger models were developed with an add-on long-distance travel data set (i.e., survey conducted in 2001, 2002 and 2009) from the NHTS (BTS, 2017). Limited by the small sample size of this data set, results of the long-distance passenger models vary from state to state. Trip rates and parameters from published NCHRP reports were also used to build the long-distance components of statewide models, including:

- NCHRP Report 716: Travel Demand Forecasting: Parameters and Techniques (NCHRP, 2012).
- NCHRP Report 735: Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (Schiffer 2012).
- NCHRP Report 765: Analytical Travel Forecasting Approaches for Project-Level Planning and Design (NCHRP, 2014a).

2.4.3 Visitor Models

Visitor travel is also explicitly represented in some statewide models. Similar to long-distance passenger travel, lack of data on visitors and their travel patterns was often cited as a significant limitation to successfully capture visitor travel in statewide models. It is noted that emerging technologies and data from cell phone usage offer opportunities to separate visitors' travel activities from those of the local residents, producing suitable data for developing visitor travel models throughout the US (NASEM, 2017).

2.4.4 Freight Models

Compared to MPO models, statewide models typically dedicate more resources to capture both short- and long-distance freight flows. Most states use the trip-based approach to model short-distance freight flows. Because the nature of freight movements is fundamentally different from the methodologies of passenger trip-based models, the limitations of trip-based truck models are well acknowledged (Holguín-Veras et al. 2013). Ohio and Oregon both developed tour-based truck component in their statewide models with promising results. Mode choice models for freight flows have also been incorporated in some statewide models. Freight mode choices are either modeled with logit-based or rule-based models. If suitable data are available, logit-based approach can identify specific factors that drive freight mode choices. Rule-based approach enables testing of sensitivities to policy scenarios without much data requirement, provided that the rules applied are well studied and tested elsewhere (NASEM, 2017).

Long-distance truck models are often built with commodity flow models based on the Freight Analysis Framework (FAF) of the Bureau of Transportation Statistics (BTS). Two principal databases of freight flows are available from FAF (BTS, 2020b):

- Origin-destination matrix of freight flows by commodity and mode of transportation in tons, value, and ton-miles.
- Estimates of freight flows by mode of transportation on major routes and segments of highways.

These freight origin-destination flow data can be converted to truckload equivalents to estimate origin-destination flow in number of trucks (Battelle, 2012).

2.4.5 Auxiliary Models

Economic Models

Many states integrated their statewide travel demand models with economic models that forecast socioeconomic variables (NASEM, 2017). These integrated economic models allow states to test how demographic and socioeconomic growth scenarios impact statewide travel demand. For example, the integrated economic models can predict the interdependencies between industries and population. Growth of a specific industry in a state can stimulate the growth of other industries, leading to overall employment and population growth in the state. Feeding the economic and population projection into travel demand models can then help the states foresee potential impacts on the transportation systems.

Land Use Models

Land use models predict future land use changes based on transportation systems change and land development proposals. Land use models have been integrated with MPO travel demand models (NASEM, 2017). The integration has been shown to improve model sensitivities (Conder and Lawton, 2002). The states of Ohio and Oregon have also integrated operational land use models with statewide travel demand models.

Air Quality Models

Air quality models have been integrated with MPO travel demand models to analyze the amount of mobile-source emissions based on scenarios of transportation infrastructure investment and policy changes (NASEM, 2017). Some states (e.g., Ohio and Oregon) have used the Environmental Protection Agency's (EPA) MOtor Vehicle Emission Simulator (MOVES) (EPA, 2020) with statewide travel demand models to estimate air pollutants and greenhouse gases (GHG) emissions. Integration of MOVES with statewide travel demand models enable states to streamline the process of air quality conformity analysis and documentation for transportation projects.

2.5 Current status of statewide modeling

Currently, 40 states have developed statewide travel demand models, with Illinois being the latest addition (IDOT, 2019). Figure 4 shows a map of different model types by states across the U.S. Basic trip-based models refer to three-step (i.e., no mode choice) passenger travel models with or without a freight component. Enhanced trip-based models refer to four-step models with additional features, such as freight models based on commodity flows and/or long-distance passenger travel models. Six states developed activity-based statewide models, including California, Oregon, Idaho, Colorado, Ohio, and Maryland.

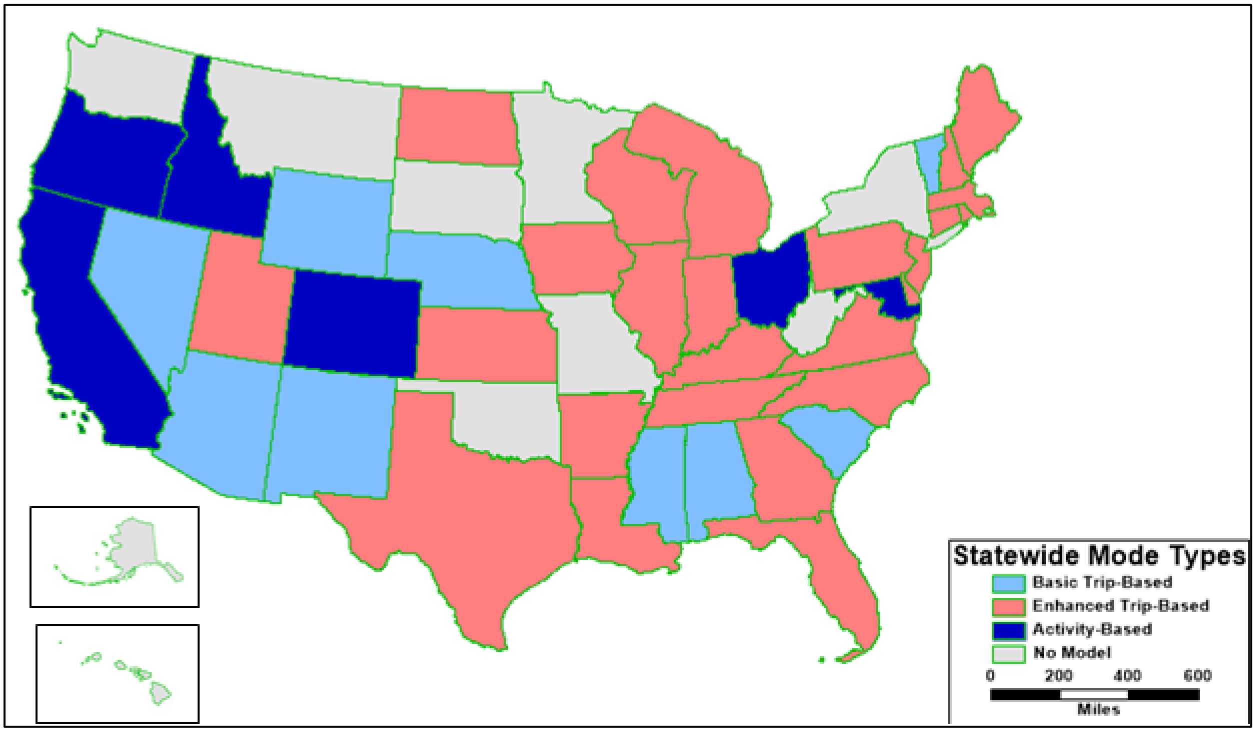


Figure 4 **Statewide Travel Demand Models by Types**

Table 2 summarizes features of existing statewide travel demand models by states. According to our updated review of existing statewide models, 17 statewide models (i.e., Florida statewide model was updated with a mode choice model after the publication of NCHRP Synthesis 514) do not explicitly model mode choices. With increasing adoption of toll roads and express lanes, the utility of models that do not consider mode choices can become limited when prediction of the share of drivers switching to proposed toll facilities is required.

Traffic variation by time-of-day is modeled in 12 of 33 states (53%) that provided valid answers to the formal survey for NCHRP synthesis 514 (NASEM, 2017). 21 states only model daily traffic without time-of-day consideration. It is noted that forecasting time-of-day traffic patterns is important for evaluation of infrastructural investment and policies designed to relieve congestion in urban and suburban highways, as congestion in these locations is most severe during the morning and evening peak hours.

For traffic assignment, majority of the states (28 of 33) adopted either static or stochastic user equilibrium assignment algorithm (Ortúzar and Willumsen, 2011). Three states (i.e., Alabama, Nebraska, and North Dakota) applied simple all-or-nothing assignment because congestion on most highways between major population regions in the states is minimal (NASEM, 2017). Iterative feedback from the assignment back to previous steps of the model (see Figure 2) to model how congestion can divert some travelers to other destinations or other modes (Ortúzar and Willumsen, 2011). Nine out of the 33 states do not use a feedback loop in their statewide models (NASEM, 2017).

Table 2 shows that 15 statewide models incorporate long-distance passenger travel demand models (NASEM, 2017). Generally, long-distance travel models are used by larger states (e.g., Texas, Colorado, Arizona, and Nevada). However, California and Florida do not have long-distance models.

21 statewide models estimate and predict short-distance truck trips (NASEM, 2017). 19 of them use trip-based models, while Ohio and Oregon use tour-based truck models. 26 states explicitly model long-distance truck trips. Long-distance truck modeling is mostly performed with commodity flow models based on origin-destination freight flow data from the Freight Analysis Framework (FAF). Some states use FAF payload factors to convert freight flows in tons into truckload equivalents.

Table 2 Summary of Statewide Travel Model Features by States

State	Network & TAZ	Baseline Data	Survey Data	Passenger Travel	Long-Distance Passenger	Freight Transport	Overall Classification
Classification Codes	1. Hwy only	1. Traffic counts only	1. None	1. Three- step with transferred parameters	1. None	1. Static trip table	1. Basic trip-based model
	2. Hwy & Transit	2. Traffic counts & GPS or cellphone data	2. NHTS	2. Four-step with estimated parameters	2. Integrated national LDT model	2. Commodity flows from FAF	2. Enhanced four-step model
			3. Custom survey	3. Activity based	3. Custom LDT model	3. Policy sensitive freight model	3. Activity-based model
Alabama	1	1	1	1	1	2	1
Alaska	No model						
Arizona	1	1	2	1	2	2	1
Arkansas	1	1	1	1	2	2	2
California	2	2	3	3	1	3	3
Colorado	2	2	3	3	1	3	3
Connecticut	2	1	3	2	1	1	2
Delaware	1	1	2	2	1	1	1
Florida	2	2	3	2	1	2	2
Georgia	2	2	2	2	2	2	2
Hawaii	Big Island only						
Idaho	2	1	3	3	3	3	3
Illinois	2	2	2	2	2	2	2
Indiana	2	1	2	2	1	2	2
Iowa	2	2	2	2	2	2	2
Kansas	2	2	1	2	3	2	2
Kentucky	1	2	2	1	2	2	2
Louisiana	2	1	2	1	1	3	2
Maine	1	2	1	2	2	2	2
Maryland	1	1	2	3	3	3	3
Massachusetts	2	2	3	2	1	1	2

Table 2, continued

Michigan	1	1	3	1	1	2	2
Minnesota	No model						
Mississippi	1	2	1	1	3	2	1
Missouri	No model						
Montana	No model						
Nebraska	1	1	1	2	1	1	1
Nevada	1	1	1	1	1	2	1
New Hampshire	2	1	3	2	1	1	2
New Jersey	2	1	2	2	1	1	1
New Mexico	1	1	1	1	1	2	1
New York	No model						
North Carolina	1	1	2	2	3	2	2
North Dakota	1	1	3	1	1	2	2
Ohio	2	1	3	3	3	3	3
Oklahoma	No model						
Oregon	2	1	3	3	3	3	3
Pennsylvania	1	1	2	2	1	1	1
Rhode Island	2	2	2	2	1	1	2
South Carolina	1	1	2	1	1	3	1
South Dakota	No model						
Tennessee	1	1	2	2	2	1	2
Texas	2	1	2	2	3	3	2
Utah	2	1	3	2	3	3	2
Vermont	1	1	2	2	3	1	1
Virginia	2	2	2	2	2	2	2
Washington	No model						
West Virginia	No model						
Wisconsin	2	1	2	2	3	3	2
Wyoming	1	1	3	1	1	3	1

(Adapted from NASEM, 2017)

2.6 Exemplary Practices of Passenger Models

2.6.1 Trip-Based Models

2.6.1.1 Trip Generation

The trip generation step of trip-based models has two components: trip production and trip attraction (Ortúzar and Willumsen, 2011). For trip production, majority of states adopted the cross-classification method, which is considered the recommended practice for trip production modeling with the trip-based approach (VDOT, 2014). A cross-classification model estimates the number of trip production by multiplying the numbers of households in a specific cross-classification (e.g., four-person household with one car) in a TAZ with corresponding trip production rate for that class. Most states derived household trip production rates for a two-variable cross-classification system of household size and auto-ownership from the NHTS (NASEM. 2017). Arkansas statewide model adopts a three-variable classification system for the TAZs, including area types (defined as a function of population and employment density), household size, and income groups (NASEM, 2017). The additional area type variable introduces additional information about land use into trip production models (VDOT, 2014). By defining TAZs with the area type class variable, trip production can be more precisely modeled than the conventional two-class system.

Trip attraction models on the other hand are typically estimated with regression models with land use characteristics of the TAZs as independent variables (Ortúzar and Willumsen, 2011). Attraction models are usually linear regression equations where the independent variables are employment by types (e.g., retail, service, or industrial) and the number of households or population.

2.6.1.2 Trip Distribution

The most common trip distribution model used in statewide modeling are the gravity models (NASEM, 2017), which are based on the mathematical function form of the law of gravity in that travel activities between two TAZs are assumed to be positively proportional to the product of trip production at one TAZ and trip attraction at the other, weighted inversely by a function of travel time between the two TAZs (Ortúzar and Willumsen, 2011). The strength of the gravity models is that they are easy to implement (i.e., only three variables needed in the simplest form) and easy to calibrate. Calibration of a gravity model involves adjusting parameters of the gravity function until the observed average trip length distribution is matched by the model (Ortúzar and Willumsen, 2011). However, gravity models cannot effectively model long-distance trips (e.g., trips over 50 miles) because the inverse weight of travel time increases drastically as distance increases such that the curve of the gravity function flattens out to values close to zero after a certain distance (Ortúzar and Willumsen, 2011). This is one of the reasons that statewide models usually incorporate separate long-distance passenger travel models (NASEM, 2017).

The logit-based destination choice model is the other commonly used model for trip distribution (NASEM, 2017). A logit destination model hypothesizes that the probability of choosing one particular TAZ depends on the ratio of the TAZ's utility, which is expressed as a function of land use characteristics of the TAZ (e.g., population, employment, and distance to the TAZ), to the sum of the utilities of all TAZs (Ortúzar and Willumsen, 2011). Some consider logit destination distribution models the best practice for trip distribution (VDOT, 2014), because the logit model form enables consideration of multiple factors that can affect destination choice, while the gravity models theoretically only allow for three variables (i.e., without considering composite variables) in the model form. In addition, the logit models do not have the limitation as gravity models in modeling long-distance trips.

In practice, gravity models are far more commonly used for statewide modeling (i.e., 22 gravity models versus 11 logit models according NCHRP synthesis 514). Generally, use of the gravity model for trip distribution is considered acceptable practice in all regions. In small regions, the gravity model for trip distribution also is considered recommended practice. In large regions, the destination choice model formulation is considered recommended practice (VDOT, 2014). It is noted that some states that used logit-based destination choice models also implemented separate long-distance travel model (NASEM, 2017), mostly because long-distance trips are different from short-distance trips in many aspects of trip-making behavior, not just destination choice (Ortúzar and Willumsen, 2011).

2.6.1.3 Mode Choice

For mode choice, two of the most commonly used models are the multinomial logit and nested-logit models (Ben-Akiva and Lerman, 1985). Similar to logit-based destination models, a multinomial logit mode-choice model hypothesizes that the probability for an individual to choose a particular mode for a trip of certain purpose depends on the ratio of the mode's utility, expressed as a function of the mode's characteristics (e.g., availability at the origin TAZ, travel time, cost, and convenience for the trip purpose), to the sum of utilities of all competing modes.

The other commonly used mode-choice model, nested logit model, hypothesizes a nested structure, in which mode choice alternatives that share similarities are pooled together. The process of choosing a mode for a particular trip purpose is represented as a multistep decision. The probability of choosing an alternative within its nest of similar alternatives is given by the ratio of the mode's utility to the sum of utilities of all alternative modes within the same nest. The probability of choosing a nest against other nests depends on the ratio of the nest's utility, which is expressed as a composite of utilities of all alternatives within the same nest, to the sum of composite utilities of all nests.

In current travel demand modeling practice, the use of either a multinomial or nested logit model is considered acceptable practice in all regions (VDOT, 2014). However, because transportation mode choices do exist in nested structures, the use of nested logit models is the most common practice. According to NCHRP Synthesis 514, 14 states were identified as using nested logit model, compared to only two states using multinomial logit (NASEM, 2017).

2.6.1.4 Time-of-Day Modeling

For time-of-day modeling, most statewide models defined four periods of a day as A.M. peak, midday, P.M. peak, and night (NASEM, 2017). The models of Ohio and Oregon divide the 24-hour day into 19 periods with hours in late evening and early morning aggregated into few periods. However, traffic assignment of the periods with little traffic is not performed for regular model runs. Although a model with fine dynamic details is capable of capturing time-dependent effects of policies intended to ease congestion as some travelers may choose to avoid congestion by traveling before or after congested hours. However, modeling more time intervals increase data requirements and computational burden for model runs.

2.6.1.5 Traffic Assignment

The state of the practice for highway assignment currently is static equilibrium assignment (Ortúzar and Willumsen, 2011). Equilibrium assignment is an iterative procedure where vehicle trips are loaded to different paths from origin to destination. During each iteration, the trips for each origin-destination TAZ pair are assigned to the shortest path connecting the origin and destination along the network. At the end of each iteration, the travel time on the links making up the path is recalculated based on the number of loaded vehicles (i.e., congestion) on the links. The iterative process ends when travel times along all possible paths connecting the origin and destination become equal. This state is called user equilibrium in that no driver could improve travel time by changing path.

User equilibrium assignment procedures are widely available in travel demand modeling software packages. It is generally recommended practice for all areas for highway assignment. In smaller areas, other methods such as all-or-nothing or incremental capacity constraint may be used (VDOT, 2014). 28 states were identified as using the user equilibrium for traffic assignment method. Alabama, Nebraska, and North Dakota applied the all-or-nothing method and only Maine adopts incremental capacity constraint method (NASEM, 2017).

2.6.1.6 Long Distance Passenger Travel

Long-distance passenger travel models are applicable only for statewide models or megaregional models (NCHRP, 2012; NASEM, 2017). With only 15 functional models in the US (NASEM, 2017), there is no consensus as to what constitutes recommended practice. As mentioned earlier, there is indeed no consistent definition for long distance trips for states that use long distance passenger models. Most statewide models define long-distance travel as one that is longer than 50 miles. Variations of distance-based definitions for long-distance trips include 75 miles and more for Georgia, 80 miles for Nevada, and 150 miles for Texas. Iowa defines long-distance trips by travel time greater than 60 minutes. For Alabama, long-distance trips are defined as those that either cross the state borders or cross more than one MPO boundary in the state (NASEM, 2017).

For trip generation, some states applied long-distance trip generation rates derived from NHTS (NASEM, 2017). Iowa and Tennessee use Federal Highway Administration's (FHWA) national long-distance person travel model (Outwater et al., 2015a) and trip rates provided in NCHRP Report 735 (Schiffer 2012). Arizona, Maryland, and North Carolina use the National Estimate of Long-Distance Travel to simulate long-distance person trips greater than 50 miles (Moeckel & Donnelly, 2011).

Eight of the 15 long-distance passenger travel models use traditional gravity models for trip distribution (NASEM, 2017), despite the known limitation of gravity models for capturing long-distance trips. Five states adopt logit-based destination choice models for trip distribution of long-distance passenger travel. Alternatively, it was noted that separate gravity models for short- and long-distance travel can be used to overcome the limitation (NASEM, 2017).

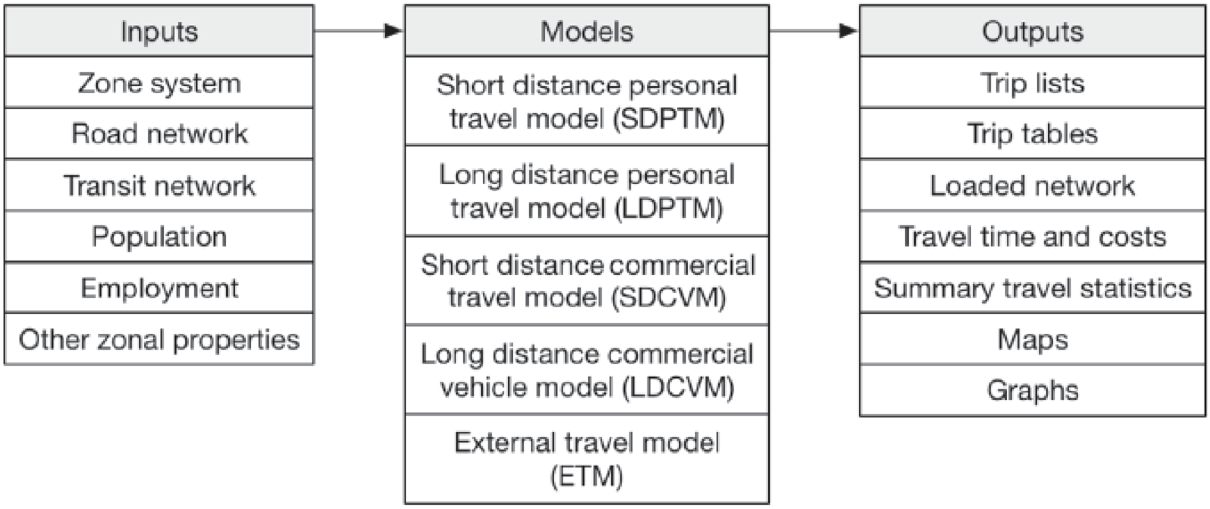
For mode choice, eight models adopted nested-logit mode choice models (NASEM, 2017). Four long-distance passenger models (i.e., Alabama, Arizona, Maryland, and Nevada) only generate long-distance trips by auto. After mode choice, long-distance passenger trips are merged with short-distance passenger and freight trips for traffic assignment.

2.6.2 Activity-Based Models

Currently, six states (i.e., California, Oregon, Idaho, Colorado, Ohio, and Maryland) developed activity-based statewide travel demand models. A common theme among the six states that opted for an activity-based statewide model is that they were challenged with unique planning issues that could not be satisfactorily resolved with a conventional trip-based statewide model (NASEM, 2017). For example, in California, stringent air quality conformity requirement was one of the drivers for the activity-based model movement (NASEM, 2017; Caltrans, 2020a). Because there are only six operational models and each of them was customarily designed and built for the specific requirements of its owner, it is difficult to generalize exemplary practices for states that are considering activity-based statewide models. A structural level summary of the California statewide model is provided here to illustrate how an activity-based model is different from a trip-based model.

Figure 5 shows the overall model structure for the second version of the California Statewide Travel Demand Model (Cambridge Systematics, 2014). All five model components involve microsimulation. For example, the Short-Distance Commercial Vehicle Model (SDCVM) use aggregate models to generate basic tour structures whose attributes are later added by microsimulation. The model system simulates passenger travel by all California residents and commercial vehicle trips by all firms for a typical weekday in the fall or spring. Development of the model system was supported by data from the California Household Travel Survey (Caltrans, 2020b).

Donnelly et al. (2010) noted that the most compelling benefit of activity-based travel demand models is their capability for evaluating pricing and equity policies, which is largely lacking for trip-based models. Because the cost of developing an activity-based model is significantly higher than the cost for a trip-based model, the decision of adopting an activity-based statewide model requires a state to carefully evaluate its planning requirements and desired model applications in order to determine if developing an activity-based model is cost-effective (NASEM, 2017).



(Source: NASEM, 2017)

Figure 5 **Structure of the California Statewide Travel Demand Model**

2.7 Limitations of Existing Models

Based on the discussions of the status and exemplary practice of statewide modeling, the following general limitations are identified in a large number of existing models:

- Lack of mode choice modeling for short- and long-distance passenger travel
- Lack of time-of-day modeling
- Lack of data for long-distance and visitor travel
- Inadequacies of trip-based freight models

It is noted that 17 states do not have a functioning mode choice component in their statewide models, while 20 statewide models produce daily traffic without distinguishing time-of-day variations. Without the capabilities for modeling mode shares and time-of-day scenarios, evaluation of emerging transportation policies such as toll roads, paid express lanes and congestion pricing cannot be reasonably achieved.

Currently, data on long-distance and visitor travel are almost non-existent. Most existing models used trip rates and parameters from a few NCHRP reports (Schiffer, 2012). Without valid data, these models cannot be validated and the utility for such models to evaluate state transportation systems is questionable.

The same problem also exists for models of freight traffic. Simple trip-based freight models built on synthetic data are limited in validity and sensitivity for policy evaluation. However, examples of tour-based freight models exist in the statewide models of Ohio and Oregon (NASEM, 2017). A major effort on large-scale data collection or incorporation of novel sources of data would be required for behavioral freight models to reach maturity as have activity-based passenger travel models.

2.8 Emerging Methods and Opportunities

There are several emerging methodological and technical trends that can offer solutions to the limitations noted above:

- Big data for both personal travel and freight traffic modeling
- Integration with a national long-distance passenger travel demand model to capture long-distance passenger travel activities
- Using networks and travel time data from cellular vehicle navigation systems.

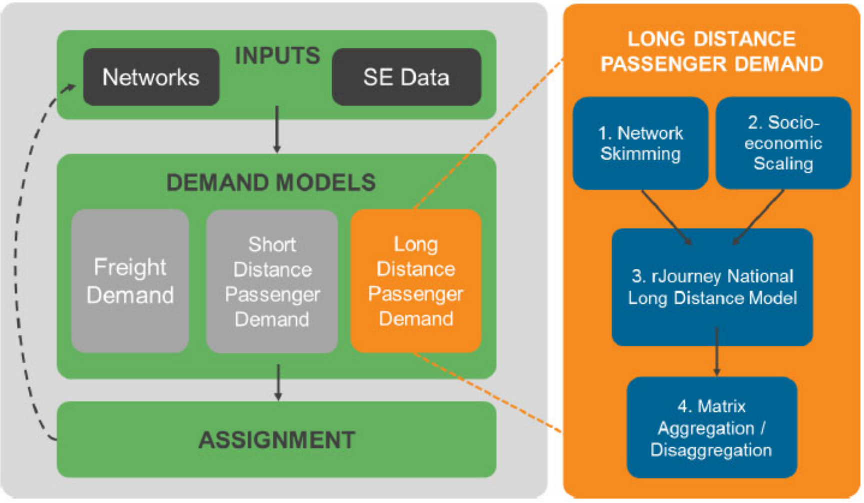
2.8.1 Big Data for Statewide Travel Modeling

Big data in this context refers to cellphone usage and/or GPS tracking records obtained from cellphone companies. Every time a cellphone is connected for cellular service or an app installed on the cellphone connects to its server, a signal is recorded with a timestamp and location coordinates. These records can be processed to identify the origins, destinations, and travel time information of the cellphone owner during a particular day. When tracking records of the same cellphone owner over a long period of time are processed, infrequent long-distance travel activities that the cellphone owner made as a visitor away from home can also be identified. Both local passenger and visitor origin-destination and travel time matrices can be constructed from these big data for transportation modeling purposes (NASEM, 2017). These data products can fill the limitation noted earlier about long-distance travel and reveal origin-destination patterns of visitors within the study area. In fact, origin-destination matrices offered by the company AirSage have been used to update the long-distance travel component in Tennessee’s statewide model (Bernardin et al., 2017).

Similarly, big data also hold promise for advancing freight traffic modeling. The American Transportation Research Institute (ATRI) offers GPS truck tracking data that contain continuously collected time-stamped coordinates for uniquely identified trucks (ATRI, 2012). Completed delivery itineraries can be retrieved for analysis over any period of time. The ATRI data have been used by modelers to estimate origin-destination matrices of statewide truck flows (NASEM, 2017). In addition to ATRI, other vendors (e.g., INRIX and StreetLight) are beginning to offer data products developed from GPS tracking of commercial vehicles. As the technologies and capability to collect and process these data reach maturity, it is expected that policy-sensitive, behavioral freight models can be developed and validated with these data.

2.8.2 Integration with a National Long-Distance Passenger Travel Demand Model

A national long-distance passenger travel demand model, named rJourney, has been developed for the FHWA (Outwater et al., 2015a). rJourney is a tour-based simulation model at national scale that can be used for evaluation of multimodal policy scenarios such as fare or service changes for commercial air travel, intercity bus, Amtrak, and highway travel (Outwater et al., 2015b). The availability of this new model represents a new opportunity for developers of statewide models. The Tennessee Department of Transportation (TDOT) chose to replace the long-distance component of TDOT statewide model that was originally built with borrowed synthetic parameters by integrating with rJourney (Bernardin, Ferdous, Sadrsadat, Trevino, and Chen, 2017). Figure 6 shows a diagram of how the integration is structured. TDOT then calibrated the integrated long-distance model with cellphone-based origin-destination matrices purchased from AirSage (2021). The success of TDOT in updating its statewide model with big data products and rJourney validates the promise of how these emerging mythologies and technologies can be used for statewide travel modeling.



(Source: Bernardin, Ferdous, Sadrsadat, Trevino, and Chen, 2017)

Figure 6 **TDOT Statewide Travel Demand Model Structure**

2.8.3 Using Network and Travel Time Data from Cellular Vehicle Navigation Systems

Companies such as Google and Waze (2020) that offer vehicle navigation services connected via cellular networks have dedicated tremendous amount of resource to develop and maintain databases on roadway networks. Although currently these companies are not offering data products on their networks and associated travel time data (NASEM, 2017), it is likely that such products may become available either from these same companies or from other vendors possessing similar technologies and resources. These products can significantly reduce the amount of labor and time involved in coding the analysis networks for the statewide travel models. Travel time data on the networks are also valuable for the purpose of calibrating and validating traffic assignment models.

2.9 Summary

A literature view extending from the findings of NHCRP Synthesis 514 (NASEM, 2017) was conducted for this research. We updated the status of statewide travel demand modeling practices to all progress made till 2020. Building on the review of current status of statewide modeling, we discussed the issues and limitations with existing statewide models and offered potential solutions in new modeling methods and technologies. Many of these emerging opportunities such as cellphone big data and integration with a national long-distance passenger travel demand model for improvement of a statewide model have been tested in other states (e.g., Tennessee) with success.

Next step for this research effort is to examine the technical details of Florida statewide travel demand model and the typical scenarios evaluated by the model in order to identify specific needs for model update and enhancement. We will also investigate emerging policy and/or global scenarios that can be evaluated with Florida statewide travel model. Sensitivity tests of the model will then be pursued by running the model for various evaluation scenarios.

3. EVALUATION OF FLORIDA STATEWIDE MODEL 7.0

This chapter describes the performance and capability of the passenger model of the latest FLSWM with respect to tasks involved in regional and statewide transportation planning. We begin with a brief overview of the FLSWM with technical details required for understanding the scenarios. Complete information of the FLSWM is available in the model documentation (FDOT, 2020a). Evaluation of FLSWM's passenger model was achieved by running the model for scenarios that were devised to assess the performance of the model and to demonstrate potential applications of the model. The scenarios focused on long distance travel, transportation planning in rural counties, and evaluation of traffic impacts from adoption of Automated, Connected, Electric, and Shared-Use (ACES) vehicles. Results of the scenario analysis were analyzed and areas for future improvement of the model were then identified.

3.1 Florida Statewide Model 7.0

Version 7.0 of the Florida Statewide Model (FLSWM), released in February 2020, represents a major update of the model (FMTF, 2020). Version 7.0 of FLSWM estimates and forecasts both passenger and freight traffic with a 2015 base year and a 2045 forecast year (FDOT, 2020a). The passenger component of FLSWM uses the traditional trip-based approach and models long-distance business (LDB) trips (i.e., trips longer than 50 miles) separately from short distance trips. For short distance passenger trips, the overall modeling process consists of trip generation, destination choice, mode share factoring, and joint traffic assignment that combines freight trucks with passenger vehicles of both short and long distance trips. LDB trips are forecasted with the process of trip generation, trip distribution by a gravity model, mode choice, and the joint traffic assignment.

The entire geographic coverage of FLSWM (Figure **7**) was divided into 9,538 Traffic Analysis Zones (TAZ), of which 8,588 zones are internal Florida zones, 59 zones are external stations located along the border with Georgia and Alabama, and the remaining 891 zones are used to modeling freight traffic to/from other U.S. states, Canada and Mexico.

The model network of version 7 (Figure **8**) was updated with 2015 capacity improvements and traffic count data obtained from Florida Department of Transportation (FDOT). The improvements data consists of projects on both Strategic Intermodal System (SIS) and non-SIS facilities that occurred between 2011 and 2015. The data do not include projects that are not capacity-related (e.g., bridge repair, resurfacing, bike lanes, sidewalks).

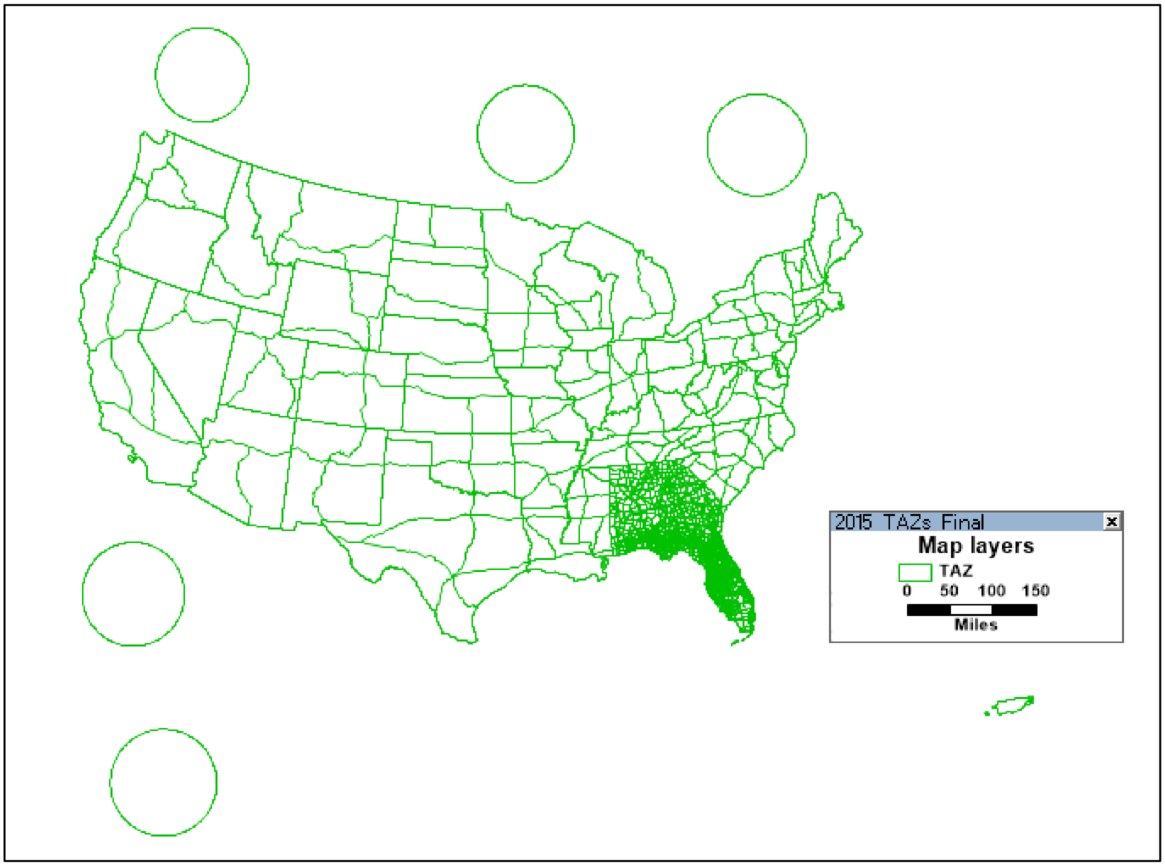


Figure 7 TAZ Coverage of FLSWM

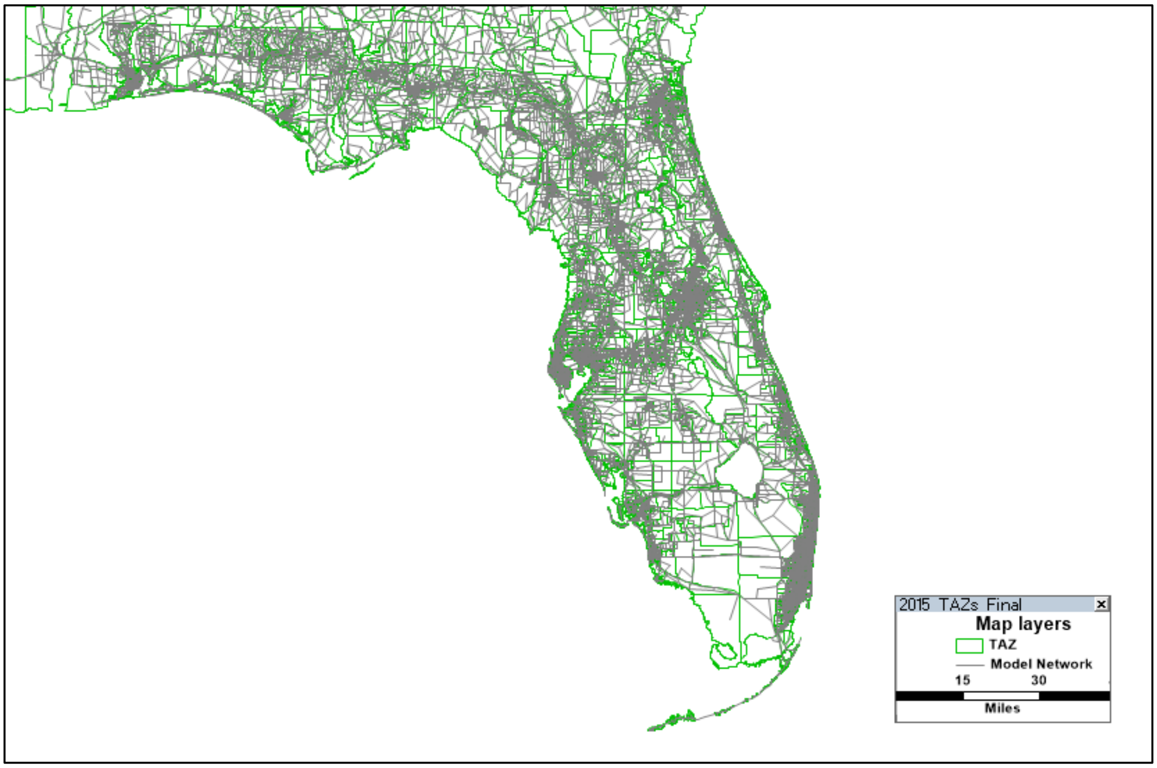


Figure 8 FLSWM Model Network and TAZs

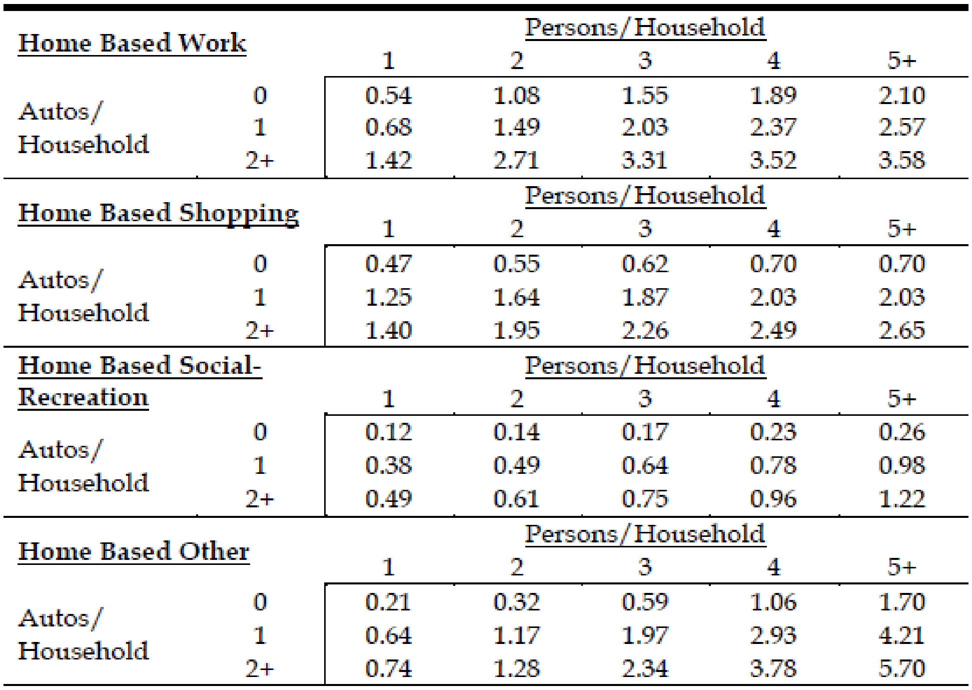
3.1.1 Trip Generation

The trip generation process of FLSWM determines trip productions (i.e., the number of trips that originate from each TAZ) for the TAZs. Eight passenger trip purposes are used in version 7 of FLSWM, including Home-Based Work (HBW), Home-Based Shopping (HBSH), Home-Based Other (HBO), Home-Based Social Recreation (HBSR), Non-Home Based (NHB), Truck-Taxi (TT), Long Distance Business (LDB) and Short Distance External-Internal or Internal-External (SDEI).

Trip attractions (i.e., number of trips ending in each TAZ) for the five primary passenger trip purposes (i.e., HBW, HOSH, HBO, HBSR, and NHB), typically required for trip distribution by gravity models, are no longer modeled with version 7, because a destination choice model replaced the gravity model that was used for version 6 of FLSWM. The TT, SDEI, and LDB trip purposes still use the gravity model approach for trip distribution.

The trip production for the four home-based trip purpose follows the cross-classification method, by which trip rates per dwelling unit vary by categories of number of autos per dwelling unit, number of persons per dwelling unit, and dwelling unit type (i.e., single family, multi-family and hotel-motel units). Table 3, Table 4, and Table 5 show home-based trip production rates for single-family, multi-family, and hotel/motel.

Table 3 Home-Based Trip Production Rates for Single-Family Dwelling Unit



Home Based Work		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.54	1.08	1.55	1.89	2.10
	1	0.68	1.49	2.03	2.37	2.57
	2+	1.42	2.71	3.31	3.52	3.58
Home Based Shopping		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.47	0.55	0.62	0.70	0.70
	1	1.25	1.64	1.87	2.03	2.03
	2+	1.40	1.95	2.26	2.49	2.65
Home Based Social-Recreation		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.12	0.14	0.17	0.23	0.26
	1	0.38	0.49	0.64	0.78	0.98
	2+	0.49	0.61	0.75	0.96	1.22
Home Based Other		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.21	0.32	0.59	1.06	1.70
	1	0.64	1.17	1.97	2.93	4.21
	2+	0.74	1.28	2.34	3.78	5.70

Source: FDOT (2020a)

Table 4 Home-Based Trip Production Rates for Multi-family Dwelling Unit

Home Based Work		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.20	0.47	0.74	1.08	1.35
	1	0.61	0.88	1.22	1.35	1.49
	2+	1.62	2.10	2.50	2.77	2.91
Home Based Shopping		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.47	0.55	0.62	0.70	0.70
	1	0.78	1.95	2.34	2.57	2.65
	2+	1.01	2.18	2.57	2.88	3.04
Home Based Social-Recreation		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.17	0.20	0.23	0.26	0.32
	1	0.38	0.61	0.84	1.10	1.53
	2+	0.44	0.69	0.96	1.27	1.77
Home Based Other		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.27	0.48	0.74	1.17	1.81
	1	0.85	1.28	1.70	2.24	3.20
	2+	1.01	1.60	2.45	3.62	4.95

Source: FDOT (2020a)

Table 5 Home-Based Trip Production Rates for Hotel/Motel

Home Based Work		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.34	0.27	0.20	0.14	0.14
	1	0.34	0.27	0.20	0.14	0.14
	2+	0.34	0.27	0.20	0.14	0.14
Home Based Shopping		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.47	2.03	3.12	3.89	4.52
	1	0.47	2.03	3.12	3.89	4.52
	2+	0.47	2.03	3.12	3.89	4.52
Home Based Social-Recreation		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.35	0.96	1.56	2.26	3.42
	1	0.35	0.96	1.56	2.26	3.42
	2+	0.35	0.96	1.56	2.26	3.42
Home Based Other		Persons/Household				
		1	2	3	4	5+
Autos/ Household	0	0.53	1.28	2.24	3.51	4.69
	1	0.53	1.28	2.24	3.51	4.69
	2+	0.53	1.28	2.24	3.51	4.69

Source: FDOT (2020a)

For each TAZ in the model, specific weights are applied to estimate the numbers of households by household sizes (i.e., persons per household, from 1 to 5+) and auto ownership cross-classifications (i.e., 0 car, 1 car, 2+ cars). The estimated numbers are then multiplied with the corresponding trip generation rates in Table 3, Table 4, and Table 5 to obtain trip productions for the four home-based trip purposes (i.e., HBW, HBSW, HBSR, and HBO).

Production for NHB for each TAZ is determined with the equation:

$$NHB\ Productions = a * Commercial\ Employment + b * Service\ Employment + c * Dwelling\ Units \quad \text{(Eq. 1)},$$

and production for TT (Truk Taxi) with:

$$TT\ production = d * Total\ Employment + e * Dwelling\ Units \quad \text{(Eq. 2)},$$

where coefficients *a, b, c, d*, and *e* vary by counties.

Attractions for TT for each TAZ are set to be equal to the productions.

Passenger trip productions at the external stations are pre-determined with 2015 AADT data from FDOT. Trips produced from external stations can be either SDEI (i.e., less than 50 miles) or LDB (i.e., 50 miles and longer). The number of trips produced and the percentage of short distance trips for each of the 59 external stations are stored in a model input file (example shown in Table 6). SDEI trip productions from an external station is determined by the trip produced form that station times the percent of short distance trips for this station. LDB trip produced from this station is the total trip produced at this external station minus the SDEI trip produced. Table 6 shows an example of trip production data for 10 of the 59 external stations.

Table 6 Example of Trip Production Data for 10 External Stations

External Station ID	Trip Production	Short Distance Percent	External Station Name	AADT 2045	County
9479	10,362	95%	SR 292 @ AL SL	11,000	Escambia
9480	18,488	90%	US 98 @ AL SL	19,420	Escambia
9481	6,144	90%	US 90 @ AL SL	6,635	Escambia
9482	35,768	75%	I-10 @ AL SL	43,567	Escambia
9483	11,078	100%	CR 184 @ AL SL	11,760	Escambia
9488	988	100%	CR 89 @ AL SL	1,100	Santa Rosa
9489	2,758	100%	SR 87 @ AL SL	3,203	Santa Rosa
9490	351	100%	CR 191 @ AL SL	400	Santa Rosa
9491	13,039	100%	CR 189 @ AL SL	14,328	Okaloosa
9492	676	100%	CR 85A @ AL SL	700	Okaloosa

Source: FDOT (2020a)

For LDB trips produced from a TAZ within the state of Florida (i.e., internal TAZ), the productions are estimated with the equation:

$$\text{LDB productions} = 0.007342 * \text{Total number of households in the TAZ} \qquad \text{(Eq. 3)}$$

The coefficient 0.007342 is the same as the version 6 of FLSWM. LDB internal attractions, the resulting trips attracted to each zone, is determined by

$$\text{LDB attractions} = 0.005544 * \text{Total employment in the TAZ} \qquad \text{(Eq. 4)}$$

LDB Internal-External trips are determined from the external file information shown in Table 6.

3.1.2 Trip Distribution

The current version of FLSWM utilizes a combination of a gravity model and a destination choice model for trip distribution. For the five main passenger internal trip purposes (HBW, HBSH, HBO, HBSR and NHB), the destination choice model is used. The TT, SDEI, and LDB trip purposes use the gravity model approach.

Gravity Model

The friction factors F_{ij} used in version 7 are the same as those of version 6. The gravity model for trip distribution of TT, SDEI, and LDB is described by the following equation:

$$V_{ij} = \frac{O_i D_j F_{ij}}{\sum_{j=1}^{n} D_j F_{ij}} \qquad \text{(Eq. 5)}$$

where:

V_{ij} = Trips (volume) originating at TAZ i and destined to TAZ j
O_i = Total trips originating at i
D_j = Total trips destined at j
F_{ij} = Friction factor for trip interchange ij
i = Origin analysis area number, $i = 1, 2, 3, \dots n$
j = Destination analysis area number, $j = 1, 2, 3, \dots n$
n = Number of analysis areas

Destination Choice Model

A gravity model for trip distribution considers only three variables in trip origins, trip destinations, and friction factors that vary by travel time between a pair of origin and destination (see Eq. 5). A destination choice model used for FLSWM considers additional sociodemographic variables such as household income and household size, employment by industry types identified by the North American Industry Classification System (NAICS) code, total population within the zone, and land area in the zone. For the five primary passenger trip purposes (HBW, HBSH, HBO, HBSR, and NHB), the destination choice model adopts the formulation of a multinomial logit model. For each potential destination TAZ i, the general form of a systematic utility function of the destination model is:

$$V_i = \sum_k \beta_k X_{ik} + \log\left(\sum_j \exp(\gamma_j)\, Z_{ij}\right) \qquad \text{(Eq. 6)}$$

where

β and γ = vectors of parameters
X = vector of qualitative variables
Z = vector of quantitative variables representing attributes of TAZ i.

The probability of choosing a particular destination zone i is given by

$$P(i) = \frac{\exp\,(V_i)}{\sum_j \exp\,(V_j)} \qquad \text{(Eq. 7)}$$

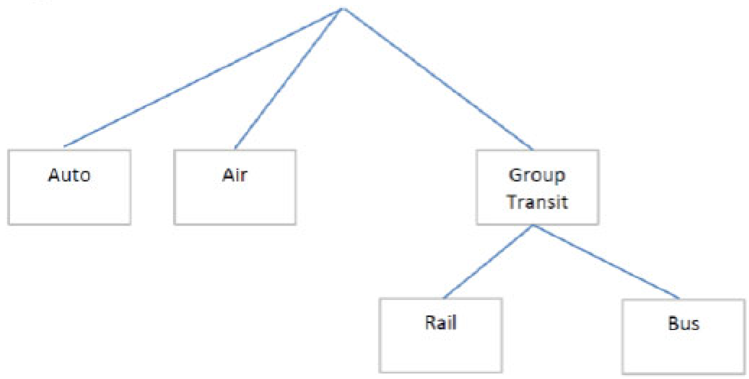
The socioeconomic data used for the TAZs includes:

- Employment by NAICS code within each TAZ. The first digit of the NAICS code describes the primary industry at a TAZ:
    - Agriculture
    - Mining, Construction, and Utilities
    - Manufacturing
    - Wholesale, Retail, Transportation and Logistics
    - General Services (not otherwise listed)
    - Medical and Educational
    - Recreation, Accommodation, and Food Service
    - Religious, and Personal Services
    - Government
- Total population within each TAZ.
- Land area within each TAZ.

3.1.3 Mode Choice

3.1.3.1 Long Distance Business Mode Choice Model

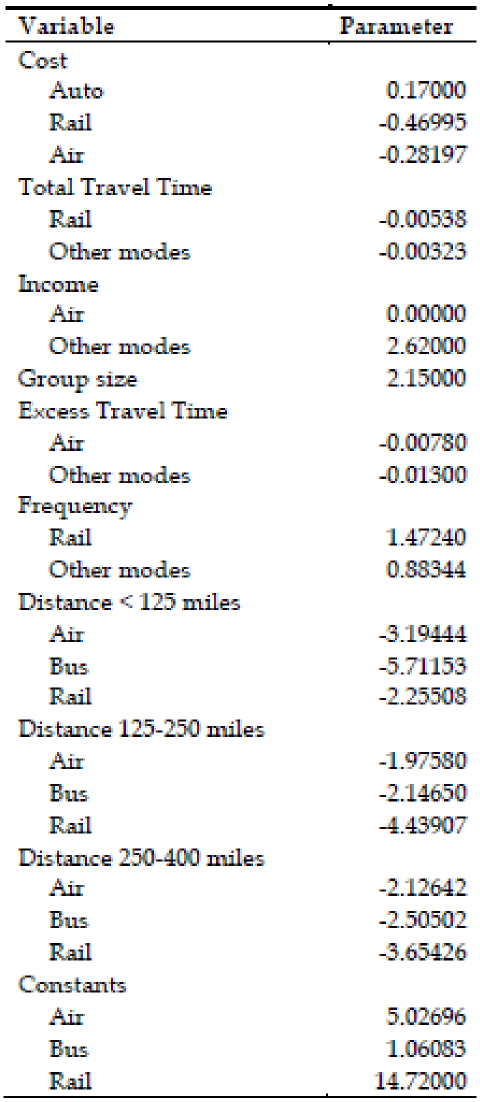
Mode choice for the FLSWM is performed separately for short distance trips and LDB trips. The mode choice model for LDB trips was transferred with modifications from the long distance mode choice model used for the Virginia statewide model (FDOT, 2020a). The Virginia model is a nested logit model with four alternatives: auto, air, bus, and rail (Figure 9). Because of lack of good data for calibration of long distance bus trips, the choices of bus and rail are aggregated to represent LDB trips by transit. Table 7 shows the coefficients used for the FLSWM LDB mode choice model.



(Source: FDOT, 2020a)

Figure 9 Virginia Statewide Model Long-Distance Mode Choice Model

Table 7 FLSWM LDB Model Choice Model Coefficients

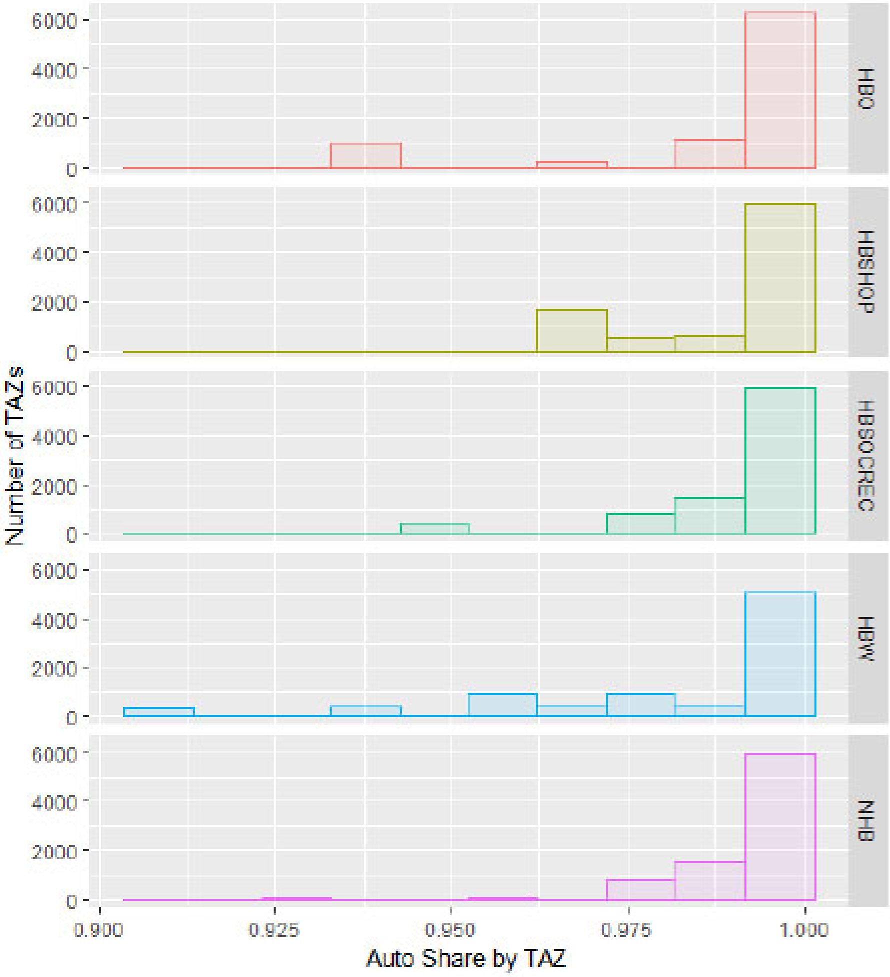


Variable	Parameter
Cost	
Auto	0.17000
Rail	-0.46995
Air	-0.28197
Total Travel Time	
Rail	-0.00538
Other modes	-0.00323
Income	
Air	0.00000
Other modes	2.62000
Group size	2.15000
Excess Travel Time	
Air	-0.00780
Other modes	-0.01300
Frequency	
Rail	1.47240
Other modes	0.88344
Distance < 125 miles	
Air	-3.19444
Bus	-5.71153
Rail	-2.25508
Distance 125-250 miles	
Air	-1.97580
Bus	-2.14650
Rail	-4.43907
Distance 250-400 miles	
Air	-2.12642
Bus	-2.50502
Rail	-3.65426
Constants	
Air	5.02696
Bus	1.06083
Rail	14.72000

Source: FDOT (2020a)

3.1.3.2 Short Distance Mode Shares

Short distance trips are modeled with a mode share factoring process that removes a portion of origin-destination flows as transit trips. The mode shares between auto and local transit were estimated for each TAZ with 2009 National Household Travel Survey (NHTS) data (). The results of the estimation were used to factor the mode choices for each TAZ. The factoring process essentially removes the estimated transit trips from total passenger trips to arrive at trips by automobiles for traffic assignment, which load the auto trips onto the model network. Figure 10 shows the frequency distribution of auto shares of the TAZs by trip purposes.



(Source: FDOT, 2020a)

Figure 10 Frequency Distribution of Auto Shares by FLSWM TAZs

3.1.4 Traffic Assignment

The traffic assignment stage is the last step of the four-step modeling process for passenger trips. The traffic assignment routine of FLSWM uses the multi-class user equilibrium technique. There are seven trip classes in the assignment module, including:

1. Low Value of Time (VOT) toll users in autos
2. Medium VOT toll users in autos
3. High VOT toll users in autos
4. SDEI and LDB (assumed to be medium VOT)
5. Truck and Taxi (also assumed to be medium VOT)
6. Medium Trucks (single unit, six-tire, two-axle intermediate size trucks weighted between 15,000 and 30,000 lb.)
7. Heavy Trucks (large single unit and articulated trucks with more than 6-tires and more than 2-axles)

The numbers of vehicles in classes from 1 to 5 are predicted by the passenger model of FLSWM. The numbers of medium and heavy truck classes are predicted by FreightSIM. The truck classes are assumed to be in the medium VOT category..

3.2 Scenario Analysis

Three groups of scenarios were devised for the purpose of evaluating the performance and capability of FLSWM. The first group involves three future development scenarios to assess the sensitivity of FLSWM with respect to prediction of long distance travel within the state. The second group involves a typical highway project in a rural county to demonstrate how FLSWM can be used for counties not covered by regional travel demand models. The third group examines the potential for FLSWM to be used for forecasting the traffic impacts of ACES vehicle adoption.

3.2.1 Long Distance Travel Scenarios

To assess the sensitivity of the FLSWM with respect to long distance travel (i.e., trips longer than 50 miles) both within the state (i.e., internal-internal trips) and across the state borders (i.e., internal-external trips), three hypothetical 2045 development scenarios were conceived. Each of the scenarios involves increased trip productions and attractions at a major urban area and/or the external stations. For example, in one scenario, we increased the numbers of projected 2045 population, households, and employments for all TAZs in Orange County by 10% and ran the 2045 future scenario with the increased trip productions and attractions. Orange County (i.e., where the city of Orlando is located) is chosen to be the urban area for the trip production and attraction increase because it is geographically central such that distribution of long distance trips can theoretically cover the entire state. The model results of the scenario are compared with the 2045 reference scenario (i.e., original 2045 projection without increased population and employment). Trip length distributions of the two scenarios were compared to assess the proportion of the increased trips that are long distance (i.e., longer than 50 miles). Table 8 lists the details of the three scenarios with their purposes, specific changes to the model inputs, and output metrics assessed. Figure 11 shows the map with locations of the counties and external stations involved in these three scenarios.

Table 8 Scenarios for Assessment of Long Distance Business Model Sensitivity

Scenario	Purpose	Changes to model inputs	Output Metrics
2045 Reference	Serve as the reference for comparison with the other three scenarios	No change is made to the original 2045 projection of population, households, and employments	Trip length distribution of LDB trips
2045 Orlando 10%	Examine how increases in trip production and attraction of a city change long distance travel activities	Increase 2045 projected population, households, and employments by 10% for all TAZs in Orange County.	
2045 External Stations 10%	Examine how increases in trip productions of external stations change long distance travel activities	Increase2045 projected trip production values of all external stations by 10%	
2045 Orlando 10% + External stations 10%	Examine how increases in trip productions and attractions of a city as well as the trip productions at external stations change long distance travel activities	Increase 2045 projected population, households, and employments by 10% for Orange County and increase trip production values of all external stations by 10%.	

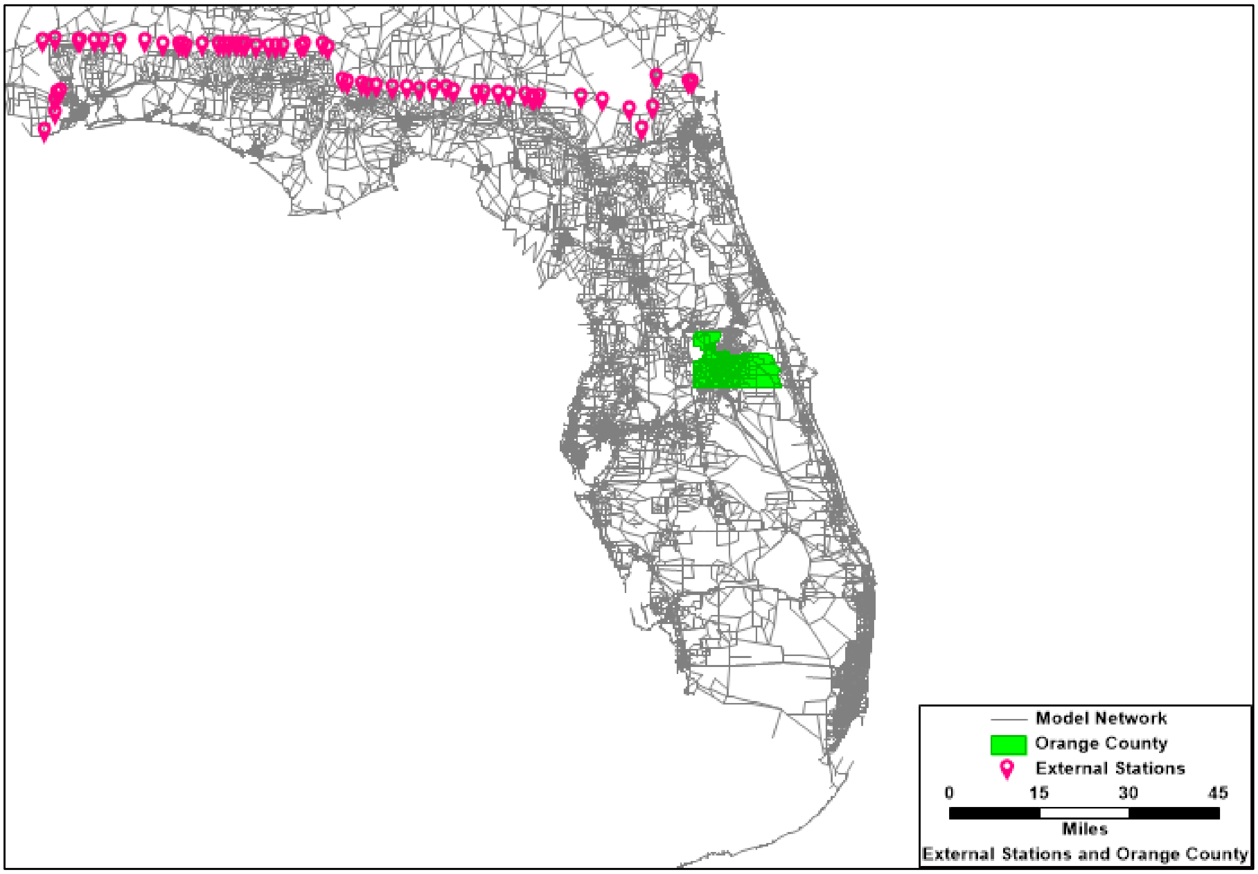


Figure 11 Geographic Locations of Orange County and FLSWM External Stations

Figure 12 shows the distribution by lengths of trip differences between the 2045 Orlando 10% scenario and the 2045 reference scenario. Each bar in Figure 12 show how many more trips the 2045 Orlando 10% scenario produced than the 2045 reference at that particular distance range. For example, approximately 220 additional trips produced by increasing the population, households, and employments in Orlando are distributed in a distance range between 50 and 70 miles.

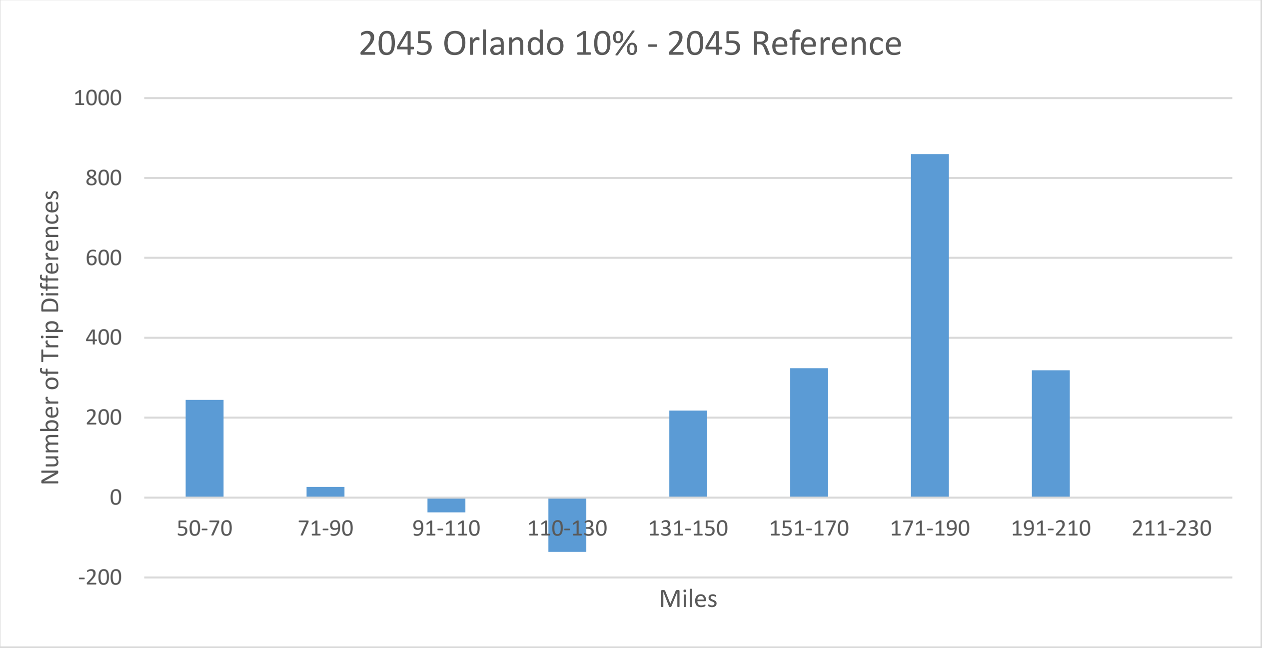


Figure 12 Distribution of Trip Differences (2045 Orlando 10% - 2045 Reference) by Trip Lengths

Figure 12 shows that majority of the additional LDB trips produced from and attracted to Orange County are distributed within the distance range between 131 and 210 miles, with 171 to 190 miles being the most distributed distance range. Because the gravity model for LDB trip distribution (see Eq. 1) accounts for the numbers of trips produced at an origin, trips destined at a destination, travel time (minutes) between the origin and destination, and the friction factors, the number of LDB trips distributed to distant TAZs depend largely on the spatial distribution of populations, households and employments relative to the location of Orange County. Figure 13 shows numbers of county population by concentric circles denoting driving distances away from Orlando. The approximate distance for each circle was estimated with Google Maps by averaging the driving distances between Orlando and the cities that are located at the circle.

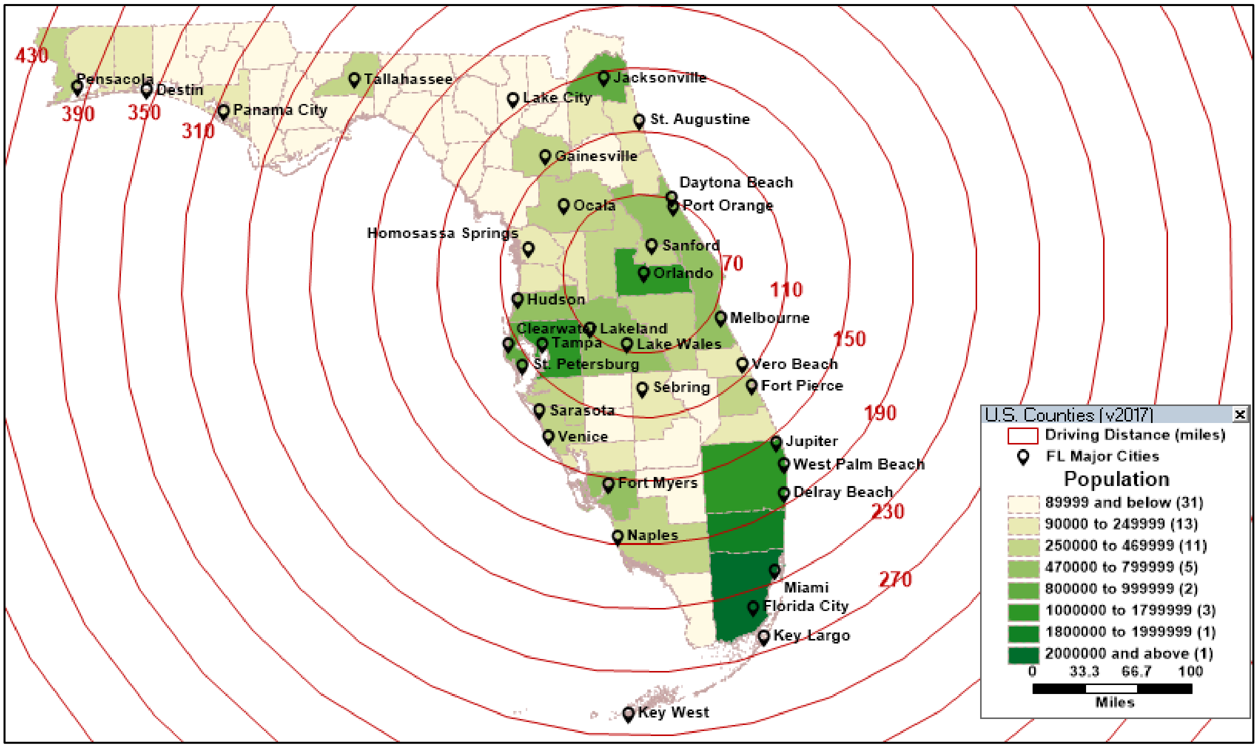


Figure 13 Spatial Distribution of County Populations by Approximate Driving Distances from Orlando

Comparing the numbers of trips distributed by distance ranges shown in Figure 12 with county populations by driving distances in Figure 13, it appears that trip distribution made by FLSWM does not reflect the spatial distribution of populations by driving distances from Orlando. For example, highly populated cities such as Tampa and St. Petersburg can be reached from Orlando within 70 to 130 miles range, but FLSWM with increased 2045 trip productions and attractions distributed less trips within this range than the original 2045 projection. In addition, the city of Miami, which is the most populated employment hub in Florida, is located approximately 230 miles away from Orlando. It is problematic that FLSWM predicts that no LDB trip will reach beyond 230 miles from Orlando.

Figure 14 shows the distribution by lengths of trip differences between the 2045 external stations 10% scenario and the 2045 reference scenario. Of the 60 external stations, most of them connect to regional routes and do not carry significant long distance trips. The external stations connecting to I-95 and I-75 at the Florida-Georgia border are the stations that produce most of the interstate long distance trips. Figure 15 shows southbound driving distances from Florida-Georgia border along I-95 and I-75. The driving distances labeled along I-95 and I-75 were also estimated with Google Maps. Driving distances from the border to major cities along I-95 are labeled in red and distances along I-75 are in blue.

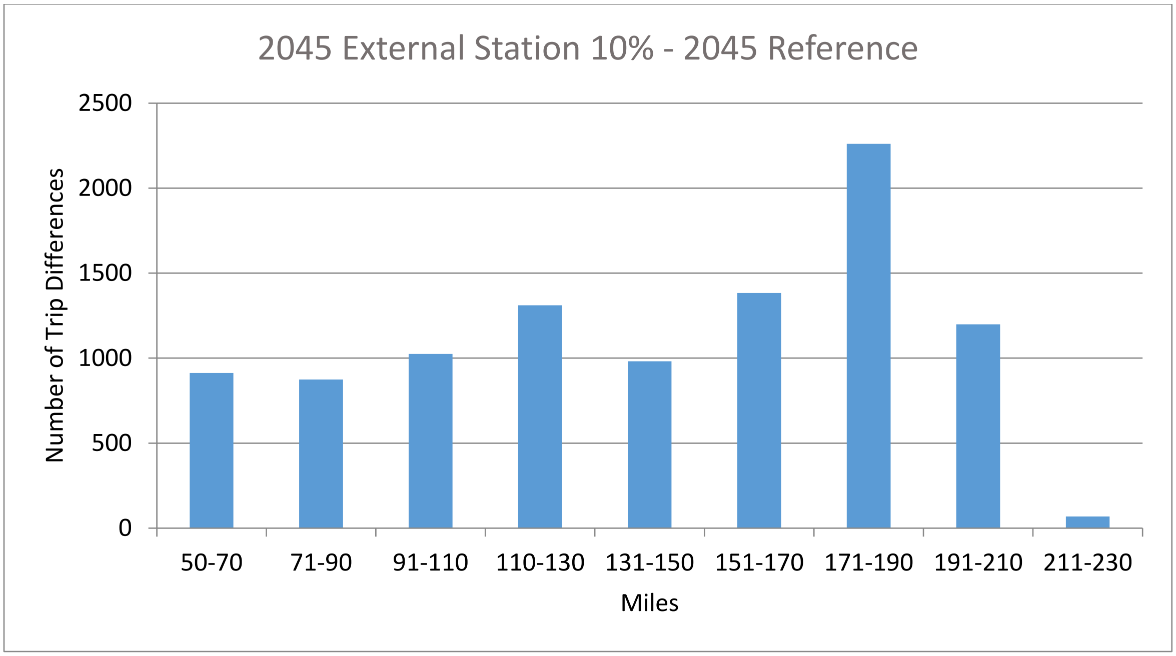


Figure 14 Distribution of Trip Differences (2045 External Stations 10% - 2045 Reference) by Trip Length

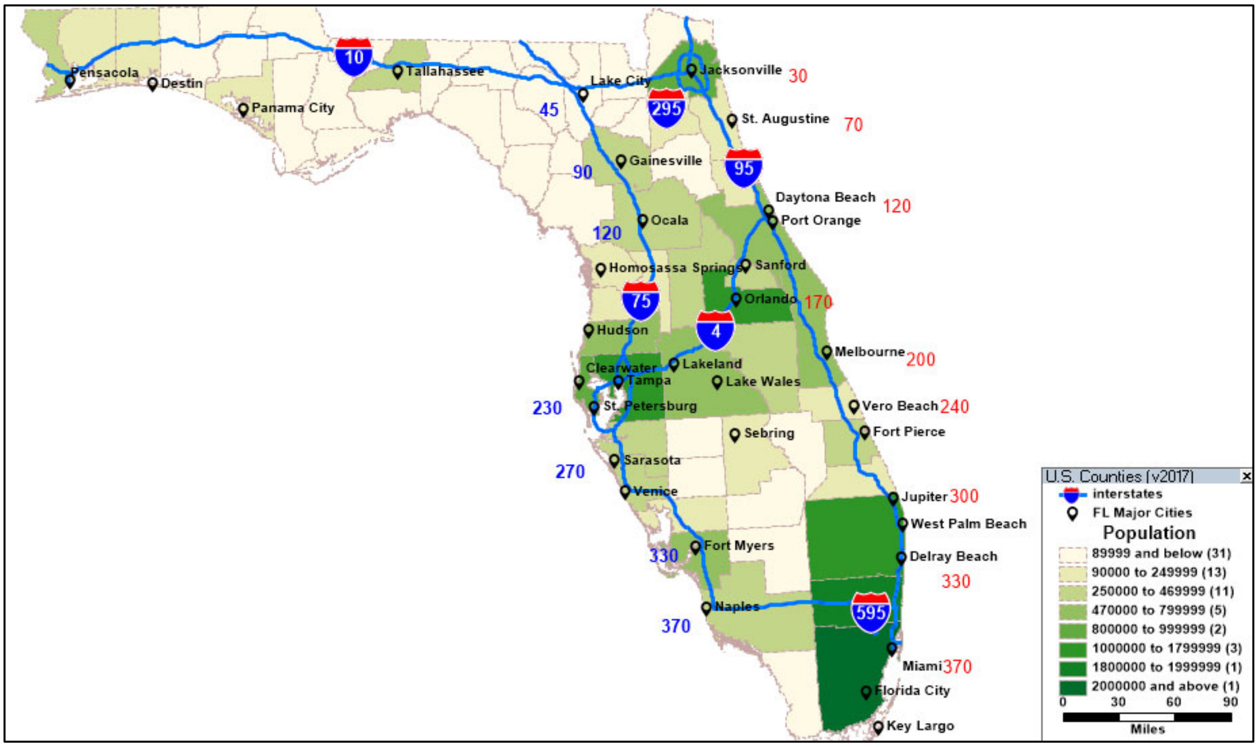


Figure 15 Southbound Driving Distances from Florida-Georgia Border along I-75 and I-95

Figure 15 shows that the additional LDB trips produced from increasing external stations trip production by 10% are distributed somewhat evenly in every 20-mile increment from 50 to 210 miles, with the exception of the 171 to 190 miles range, which has almost twice the number of trips than other ranges. It is noted that this is also the distance range that has the most trips when trip productions and attractions are increased in TAZs of Orange County (see Figure 12). There are very few trips distributed in distances from 211 to 230 miles, and no trips are distributed past 230 miles.

To assess the reasonableness of the spatial distribution of LDB trips originating from the I-95 and I-75 external stations, the distribution of trip differences by distances in Figure 14 is compared with the spatial distribution of county population in Figure 15. Along I-95, 171 to 190 miles southbound from the state border reach the population centers of Orlando in central Florida. Along I-75, the Tampa metro area, approximately 220 miles from Georgia border, is an important destination for I-75 interstate trips from Georgia. However, there are very few LDB trips distributed in in the 211-230 distance range. In addition, the fact that FLSWM does not predict any LDB trips beyond 230 miles is questionable.

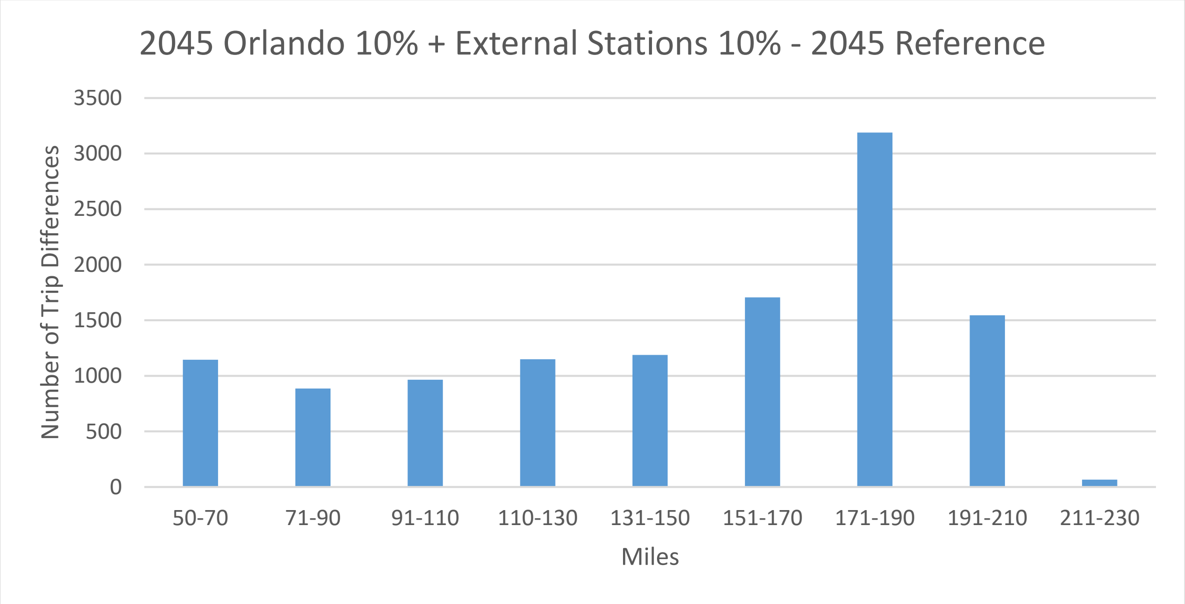
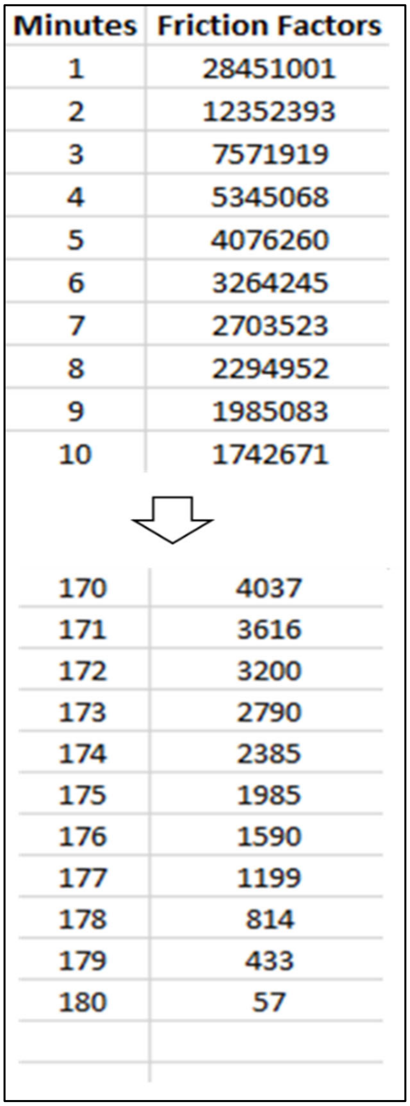


Figure 16 **Distribution of Trip Differences (2045 Orlando 10% + External Stations 10%; 2045 Reference) by Trip Lengths**

Figure 16 shows the distribution by lengths of trip differences between the 2045 Orlando 10% + external stations 10% scenario and the 2045 reference scenario. The number of LDB trips in each distance range in Figure 16 is approximately the sum of the numbers of trips of the same distance range in Figure 12 and Figure 14. For example, the number of trips in the 171 to 190 miles range is approximately 3,100 in Figure 16, which is the sum of 800 for the same distance range in Figure 12 and 2,300 in Figure 14. With this scenario, the previously noted fallacy of FLSWM's distribution of LDB trips is ascertained. With additional trips produced at both the external stations and TAZs of Orange County, theoretically the probability of having trips going beyond 230 miles should increase as the total number of additional trips increase. It is thus not reasonable that FLSWM predicts no LDB trips with distance longer than 230 miles.

Table 9 shows the friction factors used to distribute LDB trips. Because the excessive length of the friction factor table, it is truncated in the middle to demonstrate how the values of the friction factors are arranged and to show the upper and lower limits of the friction factors. The LDB friction factors vary by travel time in minutes, beginning with one minute and ending with 180 minutes. The values of friction factors decrease as travel time increase. With 180 minutes of travel time, the distance traveled with a free flow speed of 75 mph on I-95 or I-75 is approximately 225 miles. Because there are no friction factors beyond 180 minutes, by the formulation of the LDB gravity model, no LDB trips are distributed beyond 225 miles.

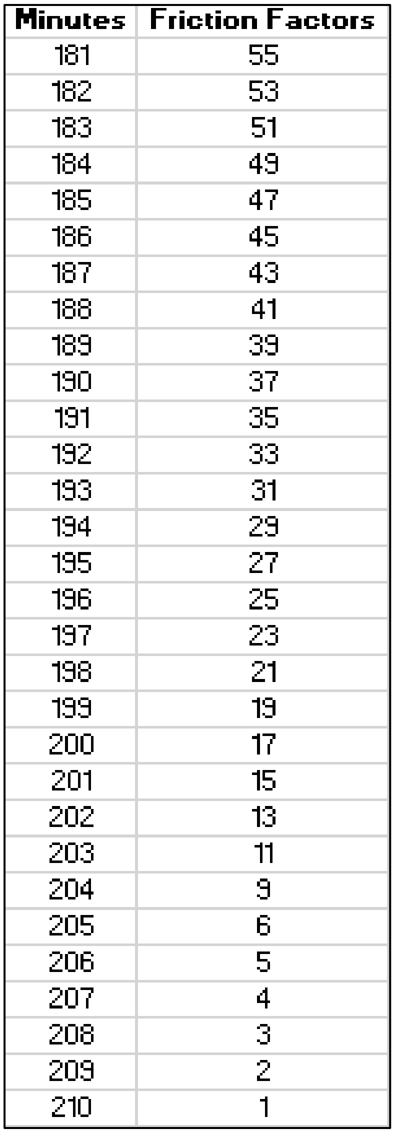
Table 9 FLSWM LDB Friction Factors



Minutes	Friction Factors
1	28451001
2	12352393
3	7571919
4	5345068
5	4076260
6	3264245
7	2703523
8	2294952
9	1985083
10	1742671
170	4037
171	3616
172	3200
173	2790
174	2385
175	1985
176	1590
177	1199
178	814
179	433
180	57

To demonstrate that the 180-minutes upper limit of the friction factors is the reason that LDB trip distribution is limited to 225 miles, we ran the 2045 reference scenario (i.e., with the original 2045 projections of populations, households, and employments) with friction factors extended to 210 minutes. For each minute of the extended friction factor table, the factor value is decreased by 2 for every minute of travel time increase. These values are used without calibration to show that trip distribution can be extended past 230 miles. Table 10 shows the extended friction factor values.

Table 10   Extended LDB Friction Factors



Minutes	Friction Factors
181	55
182	53
183	51
184	49
185	47
186	45
187	43
188	41
189	39
190	37
191	35
192	33
193	31
194	29
195	27
196	25
197	23
198	21
199	19
200	17
201	15
202	13
203	11
204	9
205	6
206	5
207	4
208	3
209	2
210	1

Figure 17 shows trip length distribution of the LDB trips for the 2045 reference scenario, distributed with the original friction factors limited by the 180-minute upper bound. It can be seen that there are no trips distributed beyond 230 miles. Figure 18 shows trip length distribution of the same scenario with extended friction factors. There are now trips distributed in distance beyond 230 miles.

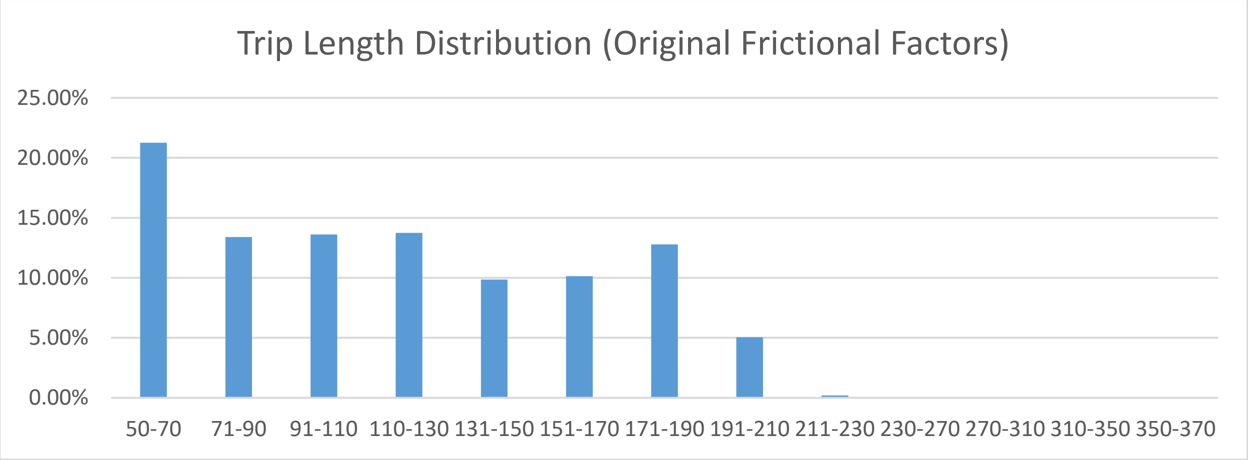


Figure 17 Trip Length Distribution of the 2045 Reference Scenario with Original Friction Factors

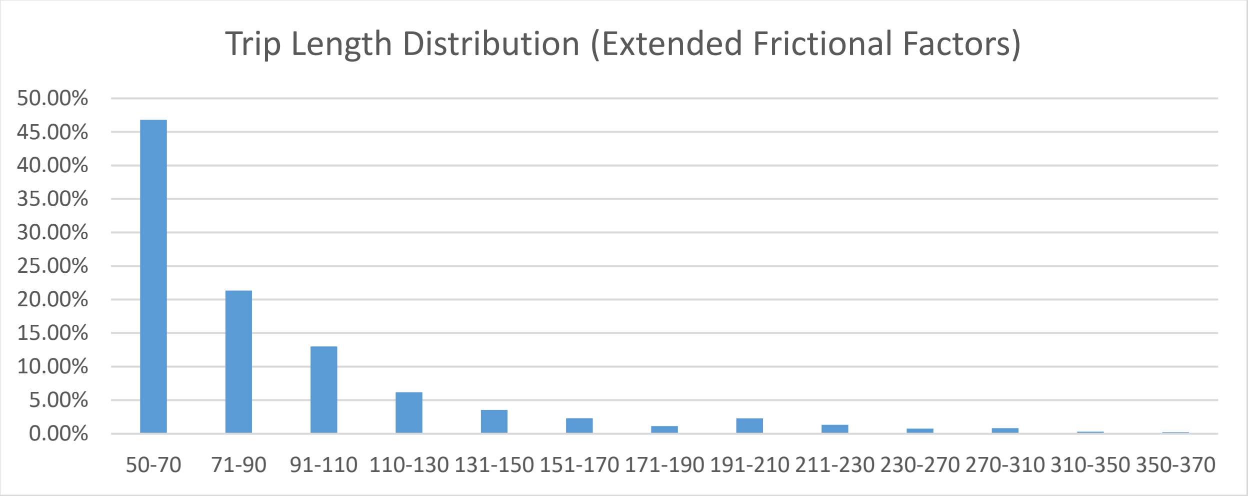
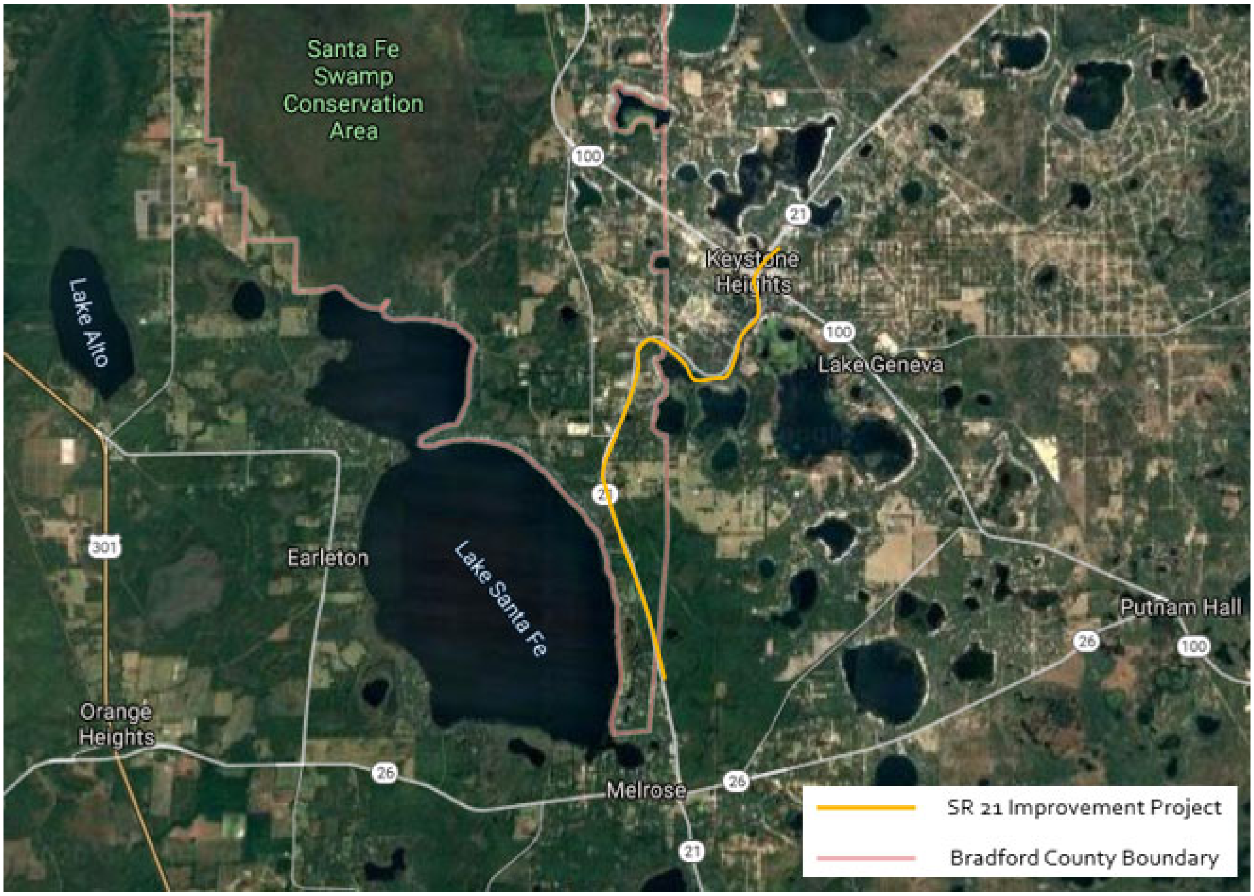


Figure 18 Trip Length Distribution of the 2045 Reference Scenario with Extended Friction Factors

3.2.2 Rural Transportation Planning Scenario

To demonstrate how FLSWM can be used for transportation planning in the rural counties of Florida, we identify a FDOT project in a rural county that is not covered by any MPO regions. The State Road 21 (SR-21) improvement project, scheduled to start in June 2020, is located in Bradford, Clay and Putnam Counties in northeast Florida (FDOT, 2020b). The project has several components, including milling and resurfacing SR-21 from the Putnam county line to north of Commercial Circle in Keystone Heights; widening the paved shoulders; improving the lighting and adding mid-block crossings and bulb-outs within the Town of Keystone Heights; and signal and pedestrian improvements at the intersection between SR-21 and SR-100. Figure 19 shows the alignment of the SR-21 improvement project with respect to Bradford county boundary.

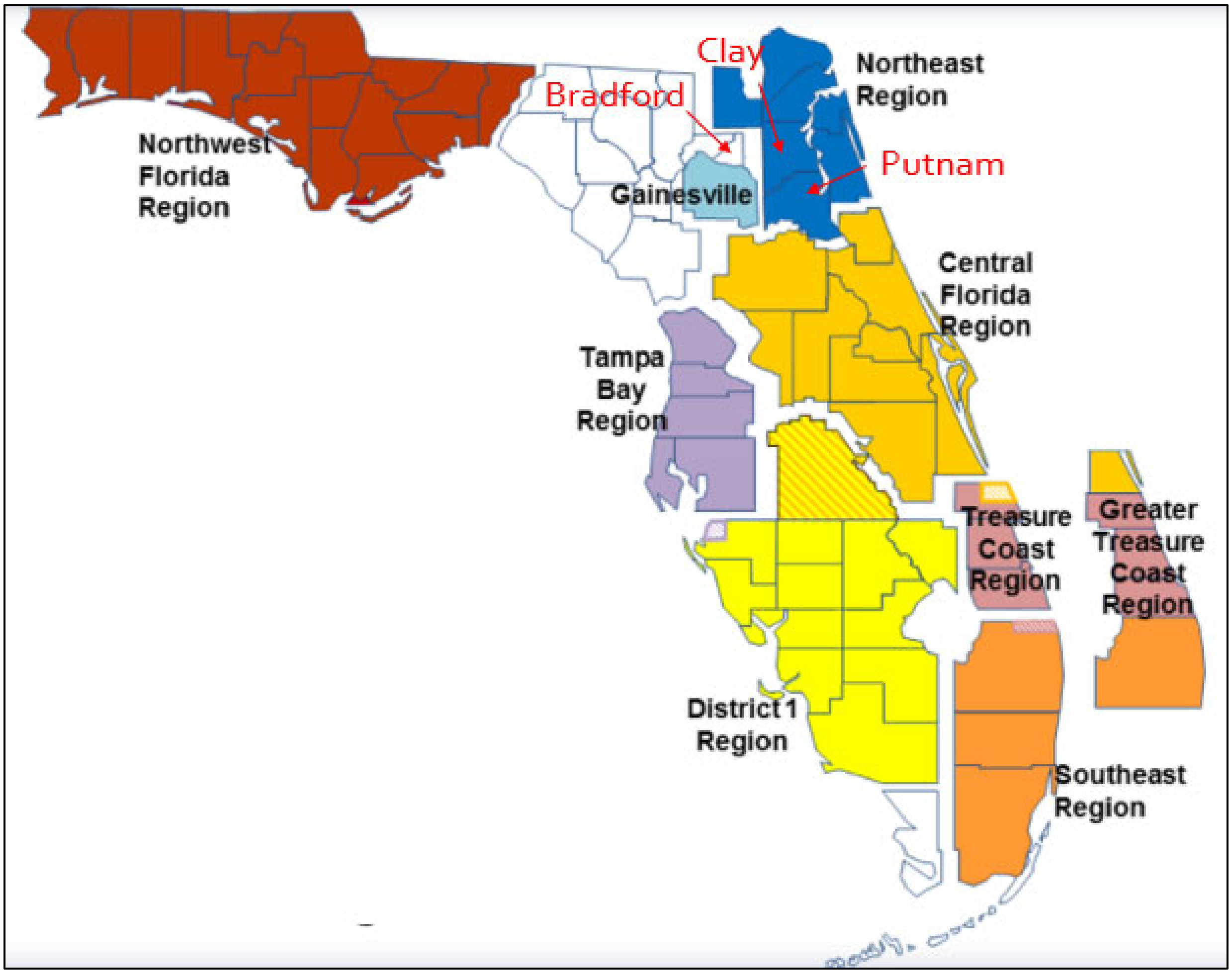
. the



(Adapted from Google Maps)

Figure 19 SR-21 Improvement Project Location

Figure 20 shows the geographic coverage of travel demand models used by all planning organizations in Florida (FSUTMSOnline.net, 2020). The colored counties in Figure 20 are included in travel demand models of Metropolitan Planning Organizations (MPO) or regional planning organizations. Only several counties (i.e., not colored) in rural areas in northeast Florida and the Monroe county containing the Florida Keys are not included in any travel demand models. Figure 20 also identifies the geographic locations of Putnam, Bradford, and Clay counties. Putnam and Clay counties are covered in the travel demand models for Northeast Region (i.e., the Jacksonville metro area) while Bradford is not covered by any travel demand model. The entire alignment of SR-21 improvement projects, which begins at the Bradford-Putnam county line and ends in Clay county, is not covered in the travel demand model of the Northeast Region. Thus, FLSWM with its coverage of the entire state can be used to model the traffic impacts of the SR-21 project.



(Source: FSUTMSOnline.net, 2020)

Figure 20 **Florida Travel Demand Model Coverage by Counties**

A critical task involved in a project development and environment (PD & E) study for highway projects in Florida such as the SR-21 improvement project is to forecast the number of traffic that will use the project once it is completed. The forecasted traffic volumes on the project are typically used for level of service analysis, crash reduction analysis as well as benefit-cost analysis. For SR-21 project, widening the shoulder width along the project alignment is expected to increase the average travel speed along the project alignment. Increased travel speed will draw more traffic to use the project until a new equilibrium of traffic in the region is reached. FLSWM with its coverage of the entire length of the SR-21 project can be used to model the amount of traffic on SR-21 at the new regional traffic equilibrium. Figure 21 shows FLSWM model network links correspond to the SR-21 project.

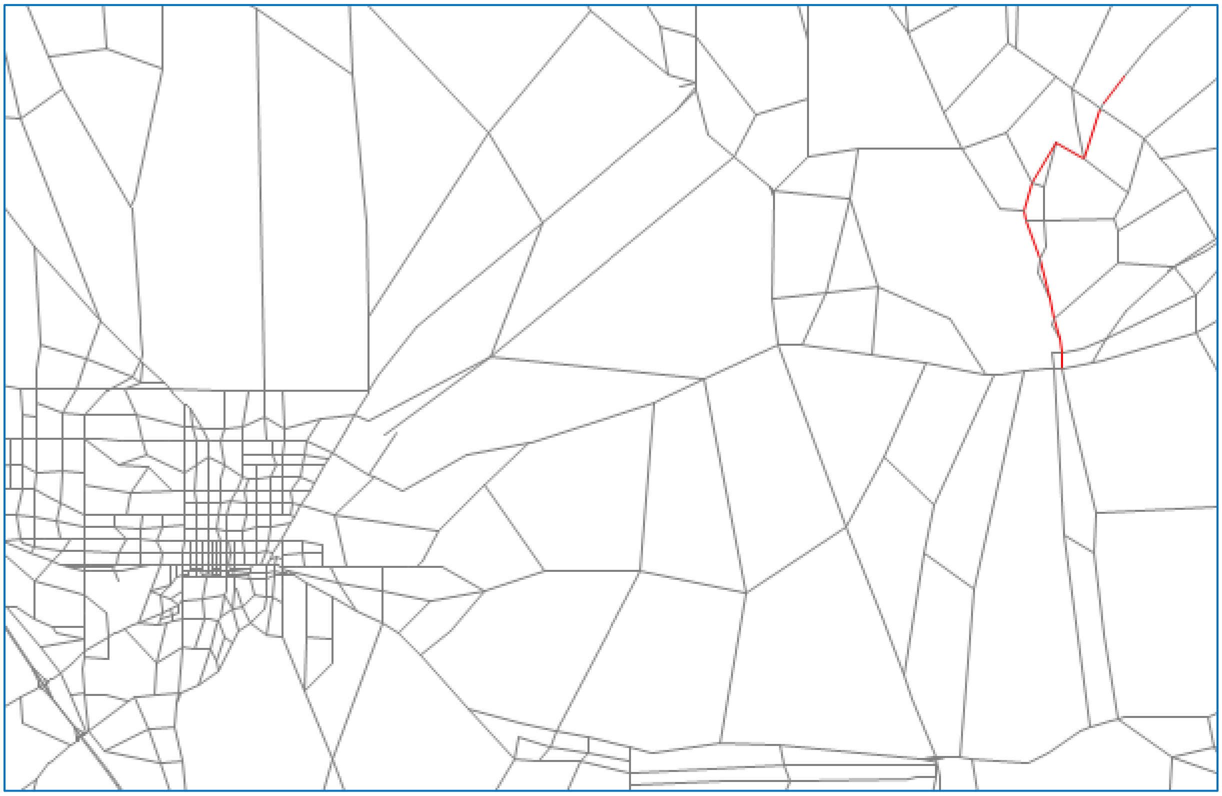


Figure 21 Representation of the SR-21 Project Alignment in FLSWM Model Network

To estimate potential travel speed increase for the SR-21 project, methodology of the most recent 6th edition of Highway Capacity Manual (HCM) is used (TRB, 2016). The Free Flow Speed (FFS) is the average travel speed that a driver can safely and comfortably negotiate along a roadway in a minimal traffic condition (TRB, 2016). The FFS can be estimated indirectly if field measurements are not available. To estimate the FFS on a two-lane highway such as the SR-21, HCM recommends the following equation:

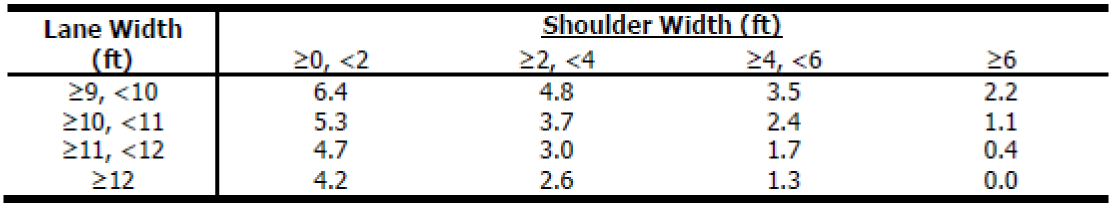
$$FFS = BFFS - f_{LS} - f_{A} \quad \text{(Eq. 8)}$$

where

FFS = free-flow speed (mi/h),
$BFFS$ = base free-flow speed (mi/h),
f_{LS} = adjustment for lane and shoulder width (mi/h), and
f_{A} = adjustment for access point density (mi/h).

The BFFS is the average travel speed that would be expected if standard lane and shoulder widths were present and there were no roadside access points such as intersections and driveways. The design speed of the highways can be used for BFFS because it is based the maximum safe speed that can be negotiated with horizontal and vertical alignment of the facility. If the design speed of the project roadway is not available, a rough estimate of BFFS might be taken as the posted speed limit plus 10 mph (TRB, 2016). Estimates of BFFS can also be based on speed data and local knowledge of operating conditions on similar facilities. Values for adjustment factors f_{LS} for lane and shoulder width in Equation 8 are included in Table 11, and Table 12 contains values for f_A (access point density).

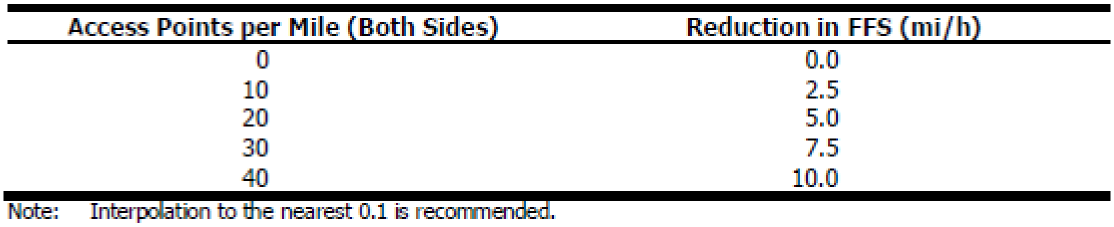
Table 11 Two Lane Highway Lane and Shoulder Width Adjustment Factor



Lane Width (ft)	Shoulder Width (ft)			
	≥0, <2	≥2, <4	≥4, <6	≥6
≥9, <10	6.4	4.8	3.5	2.2
≥10, <11	5.3	3.7	2.4	1.1
≥11, <12	4.7	3.0	1.7	0.4
≥12	4.2	2.6	1.3	0.0

(Source: TRB, 2016)

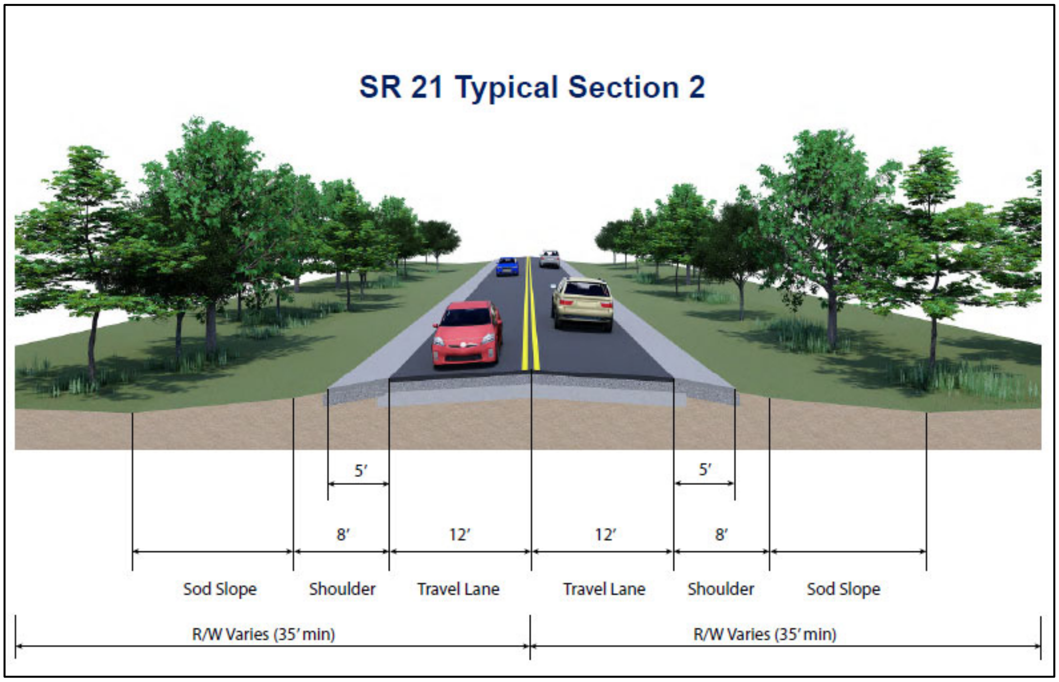
Table 12 Two Lane Highway Access Point Adjustment Factor



Access Points per Mile (Both Sides)	Reduction in FFS (mi/h)
0	0.0
10	2.5
20	5.0
30	7.5
40	10.0

Note: Interpolation to the nearest 0.1 is recommended.

(Source: TRB, 2016)



(Source: FDOT, 2020b)

Figure 22 Typical Section Diagram for the SR-21 Improvement Project

Information on lane width and shoulder width of a project can usually be identified from a project's typical section diagram. Figure 22 shows the typical section diagram of the SR-21 project. The access point density is computed by dividing the total number of unsignalized intersections and driveways on both sides of the roadway segment by the length of the segment (in miles).

Figure 22 shows that lane width of the SR-21 improvement project is 12 feet and there is going to be a 5-foot shoulder width on both sides once the project is completed. To estimate the increase in FFS, it is necessary to find out the existing lane width and shoulder width. The measurement of the existing SR-21 lane width and shoulder width was made using Google Earth (Google, 2020), which provides tools for measuring length and area of features identified on the map images. Figure 23 shows the image obtained from Google Earth for a typical section of SR-21 as of February 2019. The lane width was measured to be 12 feet and shoulder width less than 2 feet in some sections. According to the values of lane and shoulder width adjustment factors in Table 11, the value of factor f_{LS} for the existing SR-21 roadway before construction is 4.2 (i.e., 12 foot lane and shoulder less than 2 feet) and will be 1.3 (i.e., 12 foot lane and 5 foot shoulder) after the project is completed. Thus, it can be expected that there can be a 3 mph (i.e., $4.2 - 1.3 \approx 3$) of FFS increase once the project is completed. No value change for the access point factor f_A is expected for the SR-21 project because no new driveways and/or intersections are involved in the project.

(Source: Google, 2020)

Figure 23 Google Earth Image of SR-21 Typical Section as of February 2019

To predict the amount of traffic increase on SR-21 project alignment, we increased the FFS on the FLSWM network links that represent the SR-21 project (see Figure 21) by 3 mph and run the 2045 reference scenario with the increased FFS. Table 13 shows the comparison between the 2045 reference (i.e., without the SR-21 project) and results of the model run with SR-21 project.

Table 13 FLSWM Model Results for the SR-21 Project

	2045 Reference	2045 Project	2045 Reference	2045 Project
Link ID	**AB # of Vehicles**	**AB # of Vehicles**	**BA # of Vehicles**	**BA # of Vehicles**
63305	7,828	8,551	8,240	9,096
63259	6,969	7,817	6,384	6,974
63192	6,272	7,119	5,687	6,237
63168	5,881	6,710	5,308	5,866
120388	5,253	6,082	4,684	5,243
62975	5,136	5,985	4,568	5,147
62963	4,731	5,667	4,161	4,826
62964	3,765	4,430	4,334	5,269
63030	2,460	3,124	3,027	3,963
63221	2,861	3,543	3,428	4,364
63577	2,699	3,634	2,132	2,813
63596	3,499	3,720	4,252	4,567
63573	3,499	3,720	4,252	4,567
Directional Average	**4,681**	**5,393**	**4,650**	**5,303**
Directional Increase		**711**		**652**
Bi-Directional Increase				**1,364**
% Increase				**15%**

In Table 13, AB refers to one direction on the two-lane highway while BA the opposite direction. The results show that we can expect a 15% increase in traffic with the SR-21 project as compared with no project condition.

3.2.3 Adoption of Automated, Connected, Electric, and Shared-Use Vehicles Scenarios

Automated, connected, electric and shared-use vehicles (ACES) are technologies that can significantly change the way surface transportation systems operate in the future. For people who are unable to drive due to medical conditions or advanced age, automated vehicles (privately owned or shared-use) have the potential of helping them maintain the desired level of mobility and quality of life. Although the amount of traffic on highways can increase in the future with wide adoption of automated vehicles, the connectivity between these vehicles can help alleviate congestion on freeways by increasing traffic flow capacity. Forecasting future traffic conditions corresponding to various future scenarios of ACES adoption has become a task pursued by many planning organizations throughout the US in recent years (FDOT, 2018).

To examine the potential for FLSWM to be used for forecasting the traffic impacts of ACES vehicle adoption, we identified a guidance document provided by the FDOT (FDOT, 2018). This guidance is intended to help MPO in Florida find out how to account for ACES within their individual planning process and long-range transportation plan. This guidance builds on six scenarios developed by Federal Highway Administration (FHWA) that represent potential outcomes of ACES adoption with respect to different assumptions on technology capabilities, regulatory framework, consumer preferences and economic impacts. Based on these six scenarios, MPOs may develop their own scenarios that tailor to the local economy, geography, demographics and transportation network.

In developing the FDOT guide, six potential ACES scenarios (see Table 14) based on the FHWA scenarios were developed. Two regional travel demand models in Florida were used to evaluate these ACES scenarios, including:

- The Gainesville Urbanized Area Transportation (GUATS) model covering the entire Alachua County
- The Central Florida Regional Planning Model (CFRPM) that covers multiple counties in the Orlando metropolitan area

Impacts of the ACES scenarios on transportation performance including vehicle-miles traveled (VMT), vehicle hours traveled (VHT), average travel speed and congested speed were evaluated by changing key model parameters, including:

- Higher share of automobile trips to represent AV adoption by people who do not drive previously
- Increased capacity on freeways and arterial roads at different ACES adoption levels to represent improved traffic flow efficiencies produced by connected and automated vehicles
- Reduced terminal times for auto travel to represent shorter out of vehicle times associated with pick-up and drop-off by automated vehicles
- Longer average trip lengths for home-based work trips to represent users' willingness to take longer trips in automated vehicles.

Table 14 lists the six ACES scenarios and the associated modifications to the two travel demand models

Table 14 Potential Scenarios: Travel Demand Model Modifications

Model Step	Slow Roll	Niche Service Growth	Ultimate Traveler Assist	Managed Automated Lane Network	Competing Fleets	Robo Transit
	Minimum plausible change -Nothing beyond currently available technology and investments already in motion is adopted. (Baseline for comparison)	Innovation proliferates, but only in special purpose or "niche" AV zones, including retirement communities, campuses, transit corridors, urban cores, and ports.	CV technology progresses rapidly, but AV stagnates –85% of vehicles have V2X capability by 2035 due to NHTSA mandate allowing DOTs to manage congestion aggressively.	Certain lanes become integrated with CV and AV –50-60% of vehicles (75% of trucks) have automation capability for platooning in controlled settings.	Automated TNC-like services proliferate rapidly, but do not operate cooperatively. VMT doubles due to induced demand and empty vehicle repositioning.	On-demand shared services proliferate and integrate with other modes via cooperative data sharing, policies, and infrastructure.
Network	No changes	Increase in AV Zone roadway Capacities in Area Types 10-29 for Facility Types 10-19 of 33% and Area Types 10-39 for Facility Types 20-29 of 15%.	Increase in Freeway & Arterial Capacities due to more efficient trip planning. Increased capacities in Area Types 10-59 for Facility Types 10-19 of 75% and Area Types 10-59 for Facility Types 20-39 of 35%.	Special AV Lanes. Increase in Freeway & Arterial Capacities. Use of HOV lanes for AV only on Freeways in CFRPM (not in GUATS). Increased capacities in Area Types 10-59 for Facility Types 10-19 of 75% and Area Types 10-39 for Facility Types 20-39 of 35%.	Increase in Freeway Capacity in Area Types 10-59 for Facility Types 10-19 of 50%.	Increase in Freeway & Arterial Capacities due to more efficient trip planning. Increased capacities in Area Types 10-59 for Facility Types 10-19 of 75% and Area Types 10-59 for Facility Types 20-39 of 35%.
Trip Distribution	Decrease of 1 minute in Terminal Times in Central Business District and Fringe Areas. Increase of 2.5% in impedance Friction Factors for HBW to obtain longer trip lengths.	Decrease of 2 minutes in Terminal Times in Central Business District and Fringe Areas. Increase of 2.5% in impedance Friction Factors for HBW to obtain longer trip lengths.	Decrease of 1 minute in Terminal Times in Central Business District and Fringe Areas.	Decrease of 2 minutes in Terminal Times in Central Business District and Fringe Areas.	Decrease of 2 minutes in Terminal Times in Central Business District and Fringe Areas. Increase of 2.5% in impedance Friction Factors for HBW to obtain longer trip lengths.	Decrease of 2 minutes in Terminal Times in Central Business District and Fringe Areas. Increase of 5% in impedance Friction Factors for HBW to obtain longer trip lengths.
Mode Choice	Auto Trip Table Factored by 2.5% to take into account non driving trips that are now using AV. Shift of 5% of transit trips to AV.	Auto Trip Table Factored by 2.5% to take into account non driving trips that are now using AV and by 5% in AV Zones.	Auto Trip Table Factored by 2.5% to take into account non driving trips that are now using AV.	Trip Table Factored by 2.5% to take into account non driving trips that are now using AV and by 5% to take into account increases on AV lanes.	Trip Table Factored by 2.5% to take into account non driving trips that are now using AV and by 7.5% in to take into account the AV Fleets.	Trip Table Factored by 2.5% to take into account non driving trips that are now using AV and by 12.5% to take into account Robo Transit.

(Source: FDOT, 2018)

To evaluate the potentials for the FLSWM to be used for evaluating ACES adoption scenarios, we examined the differences between the modified model inputs in Table 14 and the equivalent FLSWM components. Because CFRPM, GUATS, and FLSWM were all based on the Florida Standard Urban Transportation Model Structure (FSUTMS), they share the same model network structure in that model network links are distinguished by Area Types (AT) and Facility Types (FT). AT describes the land use types surrounding the links. The AT of a link is identified with a two-digit code. The first digit, from 1 to 5, is used to categorize the primary area type and the second digit is used to categorize the subcategory. The five first digits are:

1. Central Business District (CBD)
2. CBD fringe areas
3. Residential areas
4. Outlying business areas
5. Rural areas

The FT codes are also two-digit, with the first digit being used for primary categories and the second digit for subcategories. The primary categories are:

1. Freeways and Expressways
2. Divided Arterials
3. Undivided Arterials
4. Collectors
5. Centroid Connectors
6. One-Way Facilities
7. Ramps
8. HOV Facilities
9. Toll Facilities

The FLSWM network was originally created by merging all Florida regional model networks. Theoretically, the FLSWM can be used to model ACES scenarios in the model coverage areas of CFRPM and GUATS. The modification for link capacities listed in Table 14 for CFRPM and GUATS can also be made with FLSWM. However, it is important to note that FLSWM network may not contain all the links and up-to-date details in CFRPM or GUATS, because the two regional model networks had been updated periodically since their creation.

Regarding trip distribution, the modifications to gravity model parameters in Table 14 do not apply to version 7 of FLSWM, because a destination choice model replaced the gravity model (used in version 6) for trip distribution in version 7. Friction factors do not apply to destination choice models. On the other hand, mode choice modifications in Table 14 can be made accordingly with FLSWM version 7, which incorporates a separate mode-share factoring process between the distribution and assignment of short distance trips (i.e., less than 50 miles) to remove a small portion of the origin-destination flows as transit trips. Increasing the share of auto trips due to ACES adoption can be made by modifying the more share factors before running FLWSM.

It is noted that the latest FLSWM contains a mode choice model for LDB trips. If necessary, increased shares of automobile LDB trips can be made. However, none of the six scenarios in Table 14 specifically address long distance trips by ACES.

We ran the FLSWM 2045 reference scenario with the modifications according to the Slow Roll ACES scenario in Table 14, except for the trip distribution modifications. We chose to run FLSWM for the Slow Roll scenario, because the other four scenarios with their focus on ACES use in CBDs are more suited to be evaluated with MPO or regional travel demand models. Two different ACES scenarios were used for comparisons of changes in VMT, VHT, and average speeds due to different assumptions of auto trip share increase of the Slow Roll scenario. The two scenarios are:

1. Slow Roll 2.5%: 2045 reference scenario with 2.5% auto trip increase and 5% transit trips shifted to auto
2. Slow Roll 3.5%: 2045 reference scenario with 3.5% auto trip increase and 5% transit trips shifted to auto

Comparison between Slow Roll 2.5% and Slow Roll 3.5% identifies the percent change of VMT, VHT, and average speed for 1% of auto trip share increase by ACES vehicles. We use the Alachua county for the basis of comparisons by selecting all the model network links within the boundary of Alachua county (see Figure 24). Total VMT, VHT, and average link speed for the network within Alachua county of the three scenarios were compared (see Table 15).

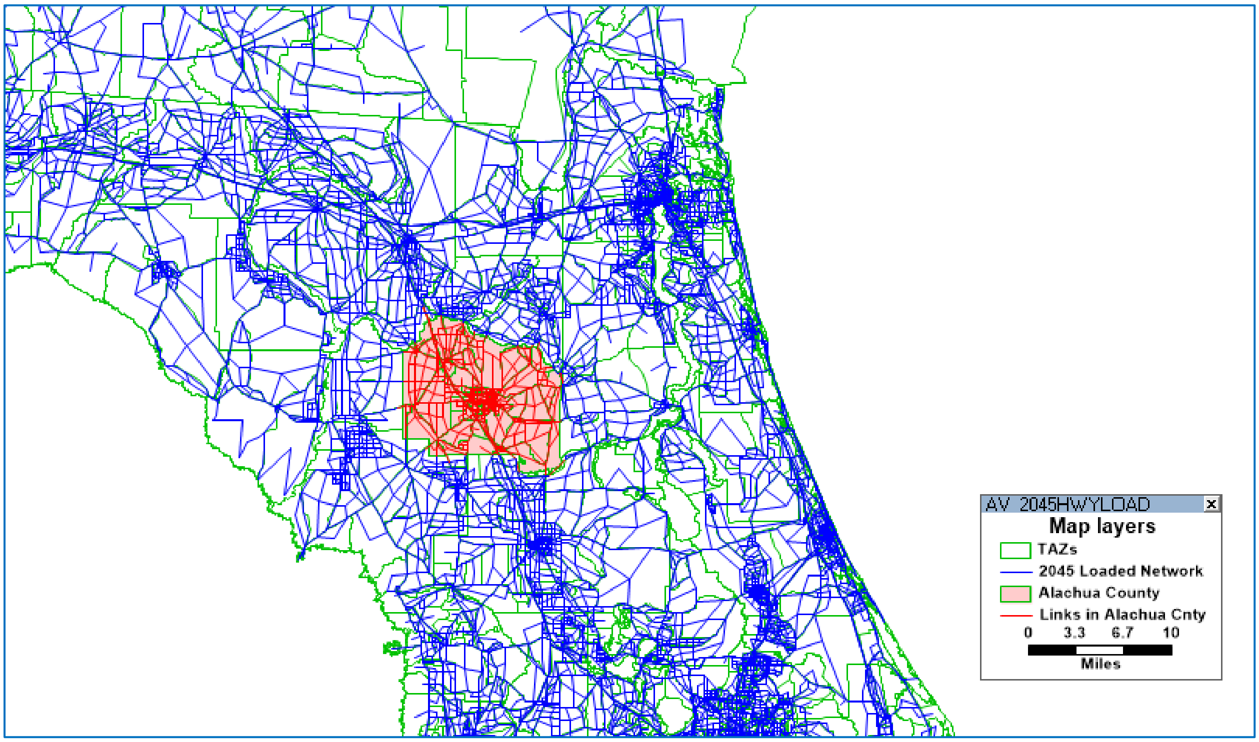


Figure 24 **FLSWM Model Network Links in Alachua County**

Table 15 **Comparison of FLSWM Results for the Slow Roll ACES Scenarios**

Alachua County Network	2045 Reference	2045 Slow Roll 2.5%	% Change between 2045 Reference and Slow Roll 2.5%	2045 Slow Roll 3.5%	% Change between Slow Roll 2.5% and 3.5%
VMT (vehicle-miles)	8,983,891	9,089,804	1.18%	9,133,054	0.48%
VHT (vehicle-hours)	229,550	233,720	1.82%	235,360	0.70%
Network Average Congested Speed (mph)	31.57	31.5	-0.22%	31.48	-0.06%

Table 15 shows that we can expect a 1.18% of VMT increase and 1.82% of VHT increase for the Alachua county if future ACES adoption follows the Slow Roll scenario with a 2.5% increase in trips made by ACES vehicles. For every 1% in ACES vehicles trips, we can expect an increase of 0.48% in VMT and 0.7% of VHT. Only a minimal decrease in average congested network speed is expected between scenarios, reflecting the fact that congestion is not a significant issue for Alachua county.

3.3. Model performance and capability

3.3.1 Long Distance Business Trips

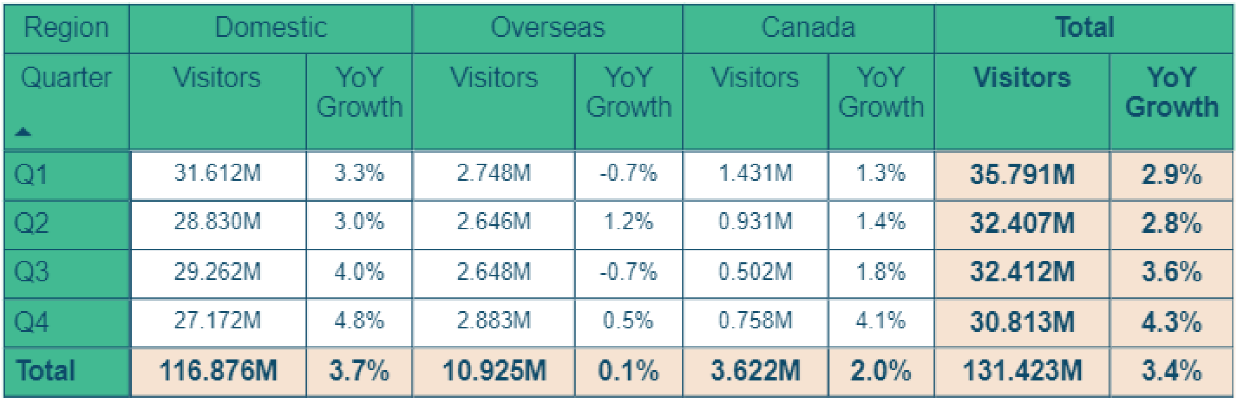
Analyses of the LDB trip scenarios show that friction factors with the upper travel time limit of 180 minutes (i.e., approximately 225 miles with free flow speed of 75 mph) do not reflect Florida geography in that the biggest urbanized area in the state (i.e., Miami) is separated by distances longer than 225 miles from the second largest (i.e., 280 miles from Tampa to Miami) and the third largest areas (e.g., 230 miles from Orlando to Miami). It is important to note that the LDB gravity model produces passenger origin-destination flows that are subsequently divided into auto, air, and rail trips by the long distance mode choice model. If the LDB passenger trips are limited to 180 minutes of driving time (225 miles in distance), LDB trips by air and rail are also incorrectly limited to 225 miles.

Because only a few counties in Florida are not covered by travel demand models (see Figure 20), most trips shorter than 50 miles are well covered by existing MPO and regional models. The long distance component is an important asset of FLSWM because it enables the evaluation of transportation projects and planning initiatives that can impact two or more travel model coverage areas. If the existing LDB gravity model is to be retained in FLSWM, the friction factors need to be recalibrated with upper limit travel time longer than 180 minutes. Another option is to replace the LDB gravity model with the destination choice model like the one used for home-based trips.

3.3.2 Visitor Travel

Another issue with version 7 of FLSWM regarding long distance travel is the lack of a component that addresses visitor trips. Version 6 of FLSWM is incorporated with a visitor model, which was calibrated in 2010?. The visitor model is discontinued due to lack of new visitor data for recalibration of the model. According to VisitFlorida (VisitFlorida, 2020), the state of Florida received 131.4 million domestic and foreign visitors in 2019 (see Table 16), with more than 30 million visitors in every quarter. With such a great number of visitors traveling on Florida highways, properly accounting for visitor trips in FLSWM can prevent over-estimation of short and long distance trips generated from Florida internal TAZs. Recalibrating the visitor model in version 6 of FLSWM with new data or creating a new statewide visitor model to account for visitor trips may need to be considered in the next FLSWM update.

Table 16 2019 Florida Visitor Estimates by Quarters



Region	Domestic		Overseas		Canada		**Total**	
Quarter	Visitors	YoY Growth	Visitors	YoY Growth	Visitors	YoY Growth	**Visitors**	**YoY Growth**
Q1	31.612M	3.3%	2.748M	-0.7%	1.431M	1.3%	**35.791M**	**2.9%**
Q2	28.830M	3.0%	2.646M	1.2%	0.931M	1.4%	**32.407M**	**2.8%**
Q3	29.262M	4.0%	2.648M	-0.7%	0.502M	1.8%	**32.412M**	**3.6%**
Q4	27.172M	4.8%	2.883M	0.5%	0.758M	4.1%	**30.813M**	**4.3%**
Total	**116.876M**	**3.7%**	**10.925M**	**0.1%**	**3.622M**	**2.0%**	**131.423M**	**3.4%**

(Source: VisitFlorida, 2020)

3.3.3 Trip Generation Socioeconomic Variables

TAZ variables for trip generation in FLSWM include population, percept households by size (i.e., persons per household, from 1 to 5+), dwelling units by types (i.e., single family, multi-family, hotel/motel), percept households by auto-ownership (i.e., autos per household, 0, 1, and 2+), and employment by types (i.e., retail, service, and total employment). These variables are effective for evaluating future development scenarios involving difference assumptions of population and employment growth. However, emerging socioeconomic trends suggest that socioeconomic variables other than population, households by size and auto-ownership, and employment may significantly change trip generation in the future. NCHRP report 750 (2014b) identified eight new socioeconomic trends, including slow population growth, aging population, structural changes in population by ethnicity, older and more diverse workforce, blurring of city and suburb, slow growth in households, increasing users of communication technologies, and salience of environmental concerns. Some of these trends share common drivers, such as aging population, longer life span, lifestyle choices of younger generations (e.g., delaying marriage and childbearing and urban lifestyle preference, etc.), and immigration. These sociodemographic trends may result in declining trip rate and VMT per capita, decreased auto ownership, increases in carpooling, and increases in non-motorized trips. While other forces may lead to contradicting effects, such as the use of transit, which may decrease with age, but can increase as Hispanics (Liu and Painter, 2012) and Millennials (Circella et al., 2016) become a larger portion of the population.

Lack of consideration for sociodemographic variables such as age and income level in the process of trip generation also limits the value for a travel demand model to be used for evaluation of ACES scenarios because adoption of these technologies is likely to be heavily influenced by the ages and income levels of the household heads. Future updates of FLSWM may consider re-structuring of the trip generation model to include other critical socioeconomic variables in the model. These additional variables have the potential of increasing both the precision and capability of future traffic prediction for FLSWM.

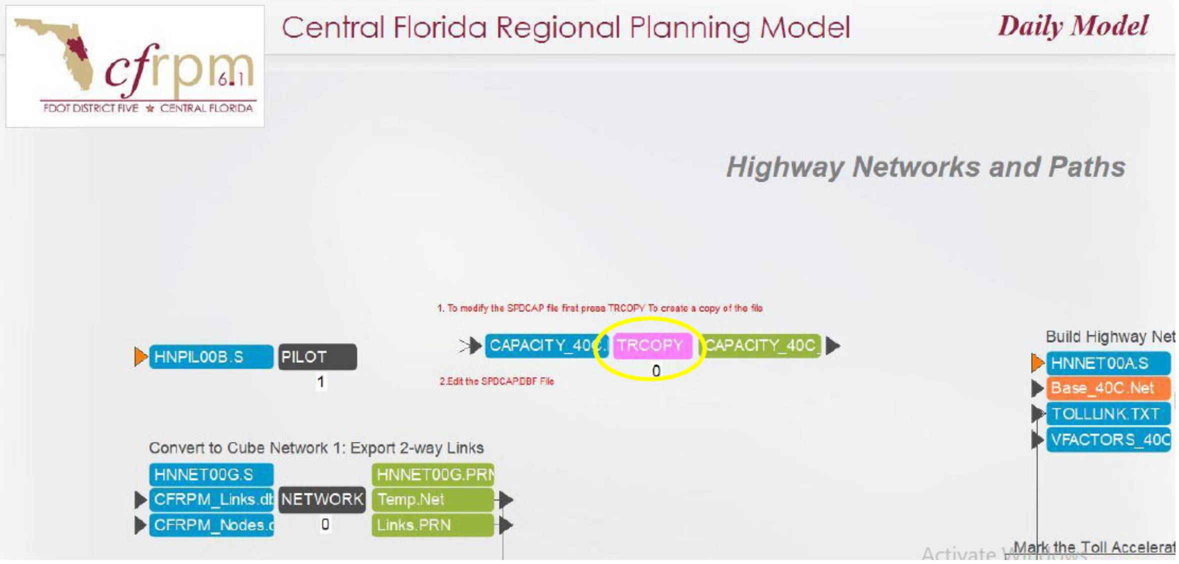
3.3.4 Daily vs. Peak Hours Traffic

The traffic assignment process of FLSWM produces network links loaded with daily traffic (i.e., number of vehicles per 24 hours). Although estimates of congested travel speed and travel time are also produced for each network link. The numbers of traffic during AM and PM peak hours are not produced, limiting the applications of FLSWM to evaluation of scenarios that are not congestion sensitive. Because technologies (e.g., ACES vehicles) and policies (e.g., congestion pricing) targeting congestion relief are becoming the focus of future transportation systems, modification of the traffic assignment process of FLSWM to incorporate estimation of peak traffic conditions may be considered. An alternative approach is to post-process the daily traffic with appropriate peak hour factors to arrive at estimation of traffic in peak conditions.

3.3.5 Input Data and Network Editing Capabilities

Running FLSWM for different future scenarios involves editing various input data and the model network. For example, to model the traffic impact of ACES scenarios shown in Table 14 (except for the Slow Roll scenario), editing the capacities of network links by area types and facility types needs to be performed. Assigning network link capacities in FLSWM is controlled by a CUBE script (i.e., NTNET00J.S). If only a small number of links need to be edited, manual editing of the link capacities can be done in CUBE’s network editing window. However, if capacity editing is required for a class of links (e.g., area type = 19 and facility type = 29), manual editing may not be feasible due to the large number of links for the intended class. Modifications of CUBE scripts controlling network attributes is then required. Because of the large number of input and output data involved in the entire FLSWM modeling process, direct modification of a script can be a challenging and time-consuming task for even established modelers who are new to FLSWM. The same challenge is also present for model runs that involve changing input data involved in applications of trip rates by cross-classification (see Table 3) for trip production. Editing the CUBE script (i.e., 01GEN00A.s) that controls this process is the only way to make changes to trip production results.

It is noted that the Central Florida Regional Planning Model (CFRPM) offers an interface (see Figure 25) for users to update link speeds and capacities. Such an approach that offers dedicated interfaces for users to edit input data can be considered to increase the applicability of future FLSWM.



1. To modify the SPDCAP file first press TRCOPY To create a copy of the file

2.Edit the SPDCAPDBF File

(Source: Beaty, 2019)

Figure 25 CFRPM Interface for Editing Network Link Speeds and Capacities

3.4 Summaries

Scenario analysis shows that LDB trip distribution friction factors with the upper travel time limit of 180 minutes do not correctly reflect the geographic coverage of Florida. Recalibration of LDB gravity model friction factors with upper limit longer than 180 minutes or replacing the LDB gravity model with a destination choice model needs be considered in the next FLSWM update. Installation of a visitor model in FLSWM also needs to be considered for the large number of visitors who visit Florida every year.

For highway projects in rural counties not covered by MPO or regional travel demand models, FLSWM can be used to evaluate the traffic impacts of such projects. However, if peak hour traffic is the concern for these highway projects, FLSWM's prediction of daily traffic volumes need to be post-processed with appropriate peak hour factors.

The traffic impacts from various scenarios of ACES adoption can be evaluated with FLSWM through assumptions of network capacities and percent increase in automobile trips by ACES vehicles. Editing large number of network links and other input data can be difficult due to lack of dedicated user interfaces.

4 NEEDS IDENTIFICATION

FLSWM was first developed over 30 years ago in 1988 with the intention of being used to model travel demand outside of MPO areas, where rapid population growth occurred in the 1990s and 2000s (NASEM, 2017). Typical planning applications of FLSWM at the time involved statewide prediction of future operational levels of service and maintenance needs with respect to specific scenarios of socioeconomic growth, highway projects and/or corridor developments (NASEM, 2017). Entering the third decades of the 21st century, the state of Florida is now preparing for its transportation systems for a different set of planning issues that are driven by emerging trends and disruptors unique to the state (FDOT, 2020c).

Considering the changing demographics and rapidly evolving technologies, Florida is facing several emerging planning and policy issues, including congestion management and pricing strategies, adaptation of travel behavior to system performance, emerging technologies and mobility services, etc. This chapter focuses on identifying current and emerging planning and policy issues in Florida to be addressed by the FLSWM. We began this by reviewing documents produced for the Florida Transportation Plan (FTP) update (FDOT, 2020c). With the review, we identified specific modeling capabilities that are required for FLSWM to address planning issues identified in FTP. Potential modifications and enhancements to FLSWM based on the limitations were then discussed.

4.1 FDOT-Long Range Visioning Session

In May of 2019, FDOT hosted the Future of Transportation in Florida workshops that included a long range visioning session (FDOT, 2019a) to initiate the process of public involvement for the 5-year update of the Florida Transportation Plan (FTP), the long-range transportation plan for the state of Florida (FDOT, 2020c). Participants of the visioning session included representatives from transportation agencies at different levels, including local, MPO, regional, and state governments, as well as members of industries, academia, professional associations, and nonprofit organizations interested in the state's transportation future. Members of the steering committee of the FTP also participated in the session. Interactive group activities were employed to solicit inputs toward specific local, regional and statewide transportation needs in Florida, as well as emerging trends, technologies, and other potential disruptors that can affect future performance and sustainability of transportation systems in Florida (FDOT, 2019a).

4.1.1 Trends and Disruptors

Table 17 identifies the top 21 most frequently selected trends and disruptors by the participants of the visioning session. While majority of these trends and disruptors identified by Florida transportation professionals reflect the demographic, technology and economic trends at the national level, there are resilience-related disruptors specific to Florida that are not pressing issues in most inland U.S. states, such as sea-level rise, storm surge, and extreme weather/temperature.

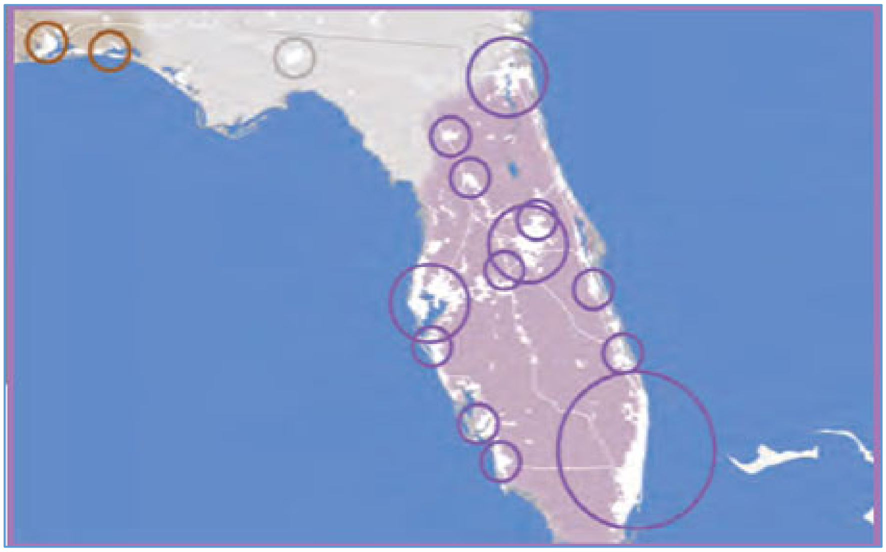
Table 17 Top 21 Florida Trends and Disruptors Identified in the Visioning Session

Florida Trends /Disruptors	Number of Times Selected	Sum of Total Score
Sea Level Rise and Increased Storm Surges	37	1,310
Rate of Deployment/Adoption of New Technology	30	972
Growing Freight Demand	24	680
Rapid Growth in Elderly Population	23	1,054
Rapid Population Growth	22	1,088
Further Suburbanization	17	684
Availability of Infrastructure for Autonomous and Connected Vehicles	14	392
Changes in Travel Behavior	14	309
Impact of Other Emerging Transportation Technologies and Communications such as 3-D Printing, Flying Cars	14	532
Increased Threat of Cybersecurity	14	410
Outdated Government Regulations	14	606
Funding/Economic	12	395
Changes in Urban/Rural Living	10	388
Growing Household Income Inequality	10	416
Loss of Skilled Workers Due to Globalization	10	247
Climate Change and Resiliency	9	345
Rapid Rate of Expansion of Ridesourcing and Ridesharing	9	134
Extreme Weather/Temperature	8	306
Rate of Adoption of Non-Fossil Fuel Sources	8	286
An Economic Recession	7	228
Rising Housing and Transport Costs	4	320

(Source: FDOT, 2019a)

A separate document, entitled Updating the Florida Transportation Plan: Emerging Trends (FDOT, 2019b), was released by FDOT in conjunction of the long-range visioning session. This document is a compilation of the latest statistics and future projections of emerging trends in Florida. Some important Florida trends identified in this document that do not appear in Table 17 include:

- Diversifying Races/Ethnicities: 20% of Florida population is foreign born and 6.9% of Florida households are limited English speakers.
- Increasing Migration and Immigration: Migration from other states and foreign countries accounted for 89% of Florida population growth between 2010 and 2017.
- Increasing Visitor Travel: Total number of visitors to Florida was 126.1 million in 2018 and is projected to increase by 42% from 2018 to 2028.
- Megaregion Formation: Florida's urban areas (i.e., urbanized areas of South Florida, Central Florida, Tampa, and Jacksonville) continue to expand with increasing business linkages between areas. The Florida peninsula is expected to become a megaregion by 2050 (see Figure 26).



Source: FDOT (2019b)

Figure 26 Formation of Megaregion of Florida Peninsula by 2050

4.1.2 Cross-Cutting Planning Issues

Participants of the session were also asked to rank the importance of a set of cross-cutting issues organized in four categories, including regional/local, state/interregional, resilience, and technology, shown in Table 18 (FDOT, 2019a).

A careful examination of issues in Table 18 reveals that all but the 7th most important cross-cutting issues in the regional/local category can be addressed by smart growth developments that promote urbanization with multi-modal facilities to reduce congestion and foster mobility and accessibility for all users. The state/interregional issues highlight the importance of multimodal transportation for long-distance travel between the state's major metro areas. Long-distance connectivity by multiple modes is also critical for system resilience such as emergency evacuation for hurricanes and effective recovery after disasters and incidences. Most of the technology issues deal with planning and preparation for emerging vehicle technologies (e.g., automated and connected vehicles, electric vehicles) for improved safety and congestion relief, and responding to changing travel preferences.

Table 18 Cross-Cutting Issues

Category	Cross-cutting Planning Issues	Rank
Regional/local	Access to jobs, schools, health care	1
	More travel choices	2
	Safety while walking and biking	3
	Less congestion	4
	Preservation of community character	5
	Well-maintained local roadways	6
	Convenient delivery of goods	7
state/ international	More international travel choices	1
	More multi-modal/multi-use corridors and bubs	2
	High-speed, high-volume international travel	3
	Connectivity between regions that are currently not connected	4
	Quick and safe emergency evacuation and response	5
	Reduced travel delays	6
	Support for global trade	7
Resilience	Transportation designed to adapt to future changes	1
	Protected transportation facilities from sea-level rise, storm damage, or other hazards	2
	Effective recovery after disaster events (access and mobility)	3
	Preservation of natural areas	3
	Maintained traffic flow after incidents and special events	5
	Managed stormwater runoff and flooding on roadways	6
Technology	Improving safety through early adoption of technology	1
	Relieving congestion or improving reliability through connected or operational technologies	2
	Appropriately responding to changing travel preferences	3
	Building infrastructure for alternative energy (e.g., changing stations for electric vehicles)	4
	Preparing for big data, data privacy, and security	4
	Planning and preparing for more automated vehicles	6
	Increasing capacity	7

(Source: FDOT, 2019a)

4.2 Florida Transportation Plan Vision Element

In May 2020, FDOT published the Florida Transportation Vision Element (FDOT, 2020c), which defines Florida's transportation vision and goals for the next 25 years. The vision element of FTP focused on seven goals for Florida's transportation future. These seven goals reflect the changing emphases such as those identified in the long-range visioning session discussed above. FDOT is currently developing the next document of the FTP, the Policy Element (FDOT, 2020c), which will describe how the vision and goals will be accomplished as well as objectives and strategies to guide all parties involved in planning, operation, and maintenance of transportation in Florida.

Goal 1: Safety and Security for Florida Residents, Visitors, and Businesses

The primary emphasis of this goal is to achieve zero fatalities and serious injuries for all modes of transportation, including bicycling and walking. Additionally, security and risk reduction for the multimodal systems are also emphasized.

Goal 2: Agile, Resilient, and Quality Infrastructure

Infrastructure defined in this goal include not only the roadway facilities, but also auxiliary systems made up of communications, sensors, and other technologies that enable the transportation systems to operate. Agility of infrastructure refers to adaptability of the transportation systems that can respond to the changing customer needs, business models, mobility options, technologies, and energy sources. The transportation infrastructure also needs to withstand and recover from threats of extreme weather events and climate change.

Goal 3: Connected, Efficient, and Reliable Mobility for People and Freight

This goal is concerned with alleviation of congestion and delay for all transportation modes of passenger and freight. Seamless transfer of passengers and freight between modes for intrastate, interstate, and international travel is also the concern of this goal.

Goal 4: Transportation Choices that Improve Equity and Accessibility

Safe and economical means for everyone to access essential opportunities such as jobs, education, and health care is the primary purpose of this goal.

Goal 5: Transportation Solutions that Strengthen Florida Economy

In addition to transporting the workforce between homes and workplaces, with ever-increasing e-commerce sales, a transportation system that grows the economy also need to provide efficient services to e-commerce centers and delivery networks. In addition, safe, economical, and reliable transportation for visitors to travel through Florida is another important economy booster for the state.

Goal 6: Transportation Solutions that Enhance Florida's Communities

This goal emphasizes the importance of providing services that address the transportation needs of diverse communities across the state, including urban and rural areas.

Goal 7: Transportation Systems that Enhance Florida's Environment

This goal advocates proactive steps to enhance and restore natural environment, while developing and maintaining the state's transportation systems that achieve all the envisioned goals.

4.3 Model Capabilities to Address Transportation Issues in Florida

Each of the seven goals in FTP Vision Element are intended to cover a wide variety of current and future transportation issues facing Florida. Thus, some of the goals overlap on specific issues. For example, Goal 2 and Goal 3 both contains elements of operational efficiency that involve adoption of ACES vehicles and other controller technologies to achieve agile and connected transportation systems. During the planning and programming processes for future transportation projects and/or policy initiatives, it is often necessary to run the FLSWM to evaluate the effectiveness for the projects to meet the FTP Vision goals. It may also be necessary to use the model results to calculate the benefit-cost ratios of the projects during programming stage of project development.

To do this, the travel demand model used for the evaluation needs to be capable of reflecting how much the outcomes change in the desired direction with implementation of the projects. For example, to evaluate the benefits of certain controller technologies for congestion relief or emission reduction, the model used need to be capable of predicting roadway volumes and speeds during peak hours (i.e., congested hours). Table 19 shows the seven goals of FTP Vision Element, the planning issues covered by the goals, and specific travel model capabilities required for evaluation of attainment of the goals.

Table 19 FTP Vision Goals, Issues Addressed, and Needed Model Capabilities

Goals	Issues Addressed	Travel Model Capabilities Required
Goal 1: Safety and Security for Florida Residents, Visitors, and Businesses	Zero fatalities and severe injuries; Safe while walking and biking	Reflect traffic impacts of projects developed with Smart Growth policies (i.e., safe mobility for users of all modes)
		Predict shares of transit and non-motorized modes use
Goal 2: Agile, Resilient, and Quality Infrastructure	Planning and preparing for increased Automated, Connected, Electric, and Share-use (ACES) vehicles	Estimate vehicle and service adoption behavior through auto ownership and mode choice models.
		Capture the potential effect of ACES vehicles on changes in trip generation rates, trip lengths, share of trips by automobiles vs. other modes, and vehicular emissions.
	Connected control technologies in sensors and controllers that can relieve congestion and improve reliability	Produce congested peak hour traffic volumes and speeds with capacity-sensitive traffic assignment methods
	Resilience (i.e., withstand and recover from extreme weather or incidences)	Support evacuation modeling with modifications of model TAZs and network.
Goal 3: Connected, Efficient, and Reliable Mobility for People and Freight	Connected control technologies in sensors and controllers that relieve congestion and improve reliability	Produce congested peak hour traffic volumes and speeds with capacity-sensitive traffic assignment methods

Table 20, continued

Goals	Issues Addressed	Travel Model Capabilities Required
	More travel choices (e.g., auto, transit, ACES vehicles, micro-mobility, and non-motorized)	**Predict shares of all modes relevant for the context of studies**
		Capture shifts in travel behavior related to ACES and other travel choices
Goal 4: Transportation Choices that Improve Equity and Accessibility	Access to jobs, schools, and health care	Destination choice model to reflect the impacts of accessibility on travel choices
	More travel choices	Predict shares of transit and non-motorized modes use
	Aging population Increasing race/ethnicity diversity Growing household income inequality	Reflect the effects of age, races/ethnicities and income levels on trip generation rates and mode choices
Goal 5: Transportation Solutions that Strengthen Florida Economy	Connectivity between region/Megaregion formation	Predict long-distance (>50 mils) business and visitor trips
	More interregional travel choices	Predict shares of modes (e.g., air, rail, automobiles) for long-distance trips
	Increasing visitor travel	Predict short- and long-distance visitor trips separately from internal trips (i.e., between internal TAZs)
Goal 6: Transportation Solutions that Enhance Florida's Communities	Aging population Increasing race/ethnicity diversity Growing household income inequality	Reflect the effects of age, races/ethnicities and income levels on trip generation rates and mode choices
	Preservation of community characters	Reflect traffic impacts of projects developed with Smart Growth policies
Goal 7: Transportation Systems that Enhance Florida's Environment	Transportation to adapt to future changes (e.g., reduce vehicle trips)	Predict potential trip reduction for projects developed with Smart Growth policies
	More travel modes	Predict shares of transit and non-motorized modes use
	Less congestion (i.e., less greenhouse gas emission)	Predict peak vs. non-peak hour traffic volumes and speeds for emission modeling

Table 19 shows that the requirement for the model to produce peak hour volumes and speed is important as the requirement overlaps in goals that address agility, efficiency, reliability, and even the environment (i.e., greenhouse emissions). Requirement for addressing multimodality is another important capability that overlaps safety, equity and accessibility, and the environment. The capability for a model to reflect the effects of projects developed with the Smart Growth is another important requirement that covers several goal areas.

4.4 Modeling Needs of FLSWM

4.4.1 Modeling Capabilities of FLSWM

To assess the capabilities of version 7 of FLSWM for evaluation of FTP goal attainment, the modeling steps, methods, input and output variables of FLSWM are summarized in Table 21 for comparison with the model requirements in Table 19. Technical details of FLSWM can be found in the model document (FDOT, 2020a).

Table 21 Summary of FLSWM Model Structure

Model Component*	Method	Input Variables	Output Variables
Trip Generation	Cross-classification by household sizes and auto ownership	• Population • Households by sizes and auto ownership • Employments	Trip productions and attraction by trip purposes for all TAZs
Trip Distribution	Short distance: multinomial logit model of destination choices	• Households by sizes and income levels • Employment by industry types identified by the North American Industry Classification System (NAICS) code • Total population • TAZ land area	Short distance origin-destination matrix
	Long-distance Business (LDB): Gravity model with friction factors	• Trip origins • Trip destinations • TAZ-to-TAZ auto free flow time matrix • Friction factors	LDB Origin-Destination matrix
Mode Choice	Short Distance: Auto trip share factoring	Short distance origin-destination matrix	Short distance automobile origin-destination matrix
	LDB: Nested logit model	• LDB Origin-Destination matrix • TAZ-to-TAZ auto free flow time matrices by auto, rail, and air	LDB origin-destination matrices by auto, rail, and air
Traffic Assignment	Multi-class user equilibrium of combined passenger vehicles and freight trucks	• Freight truck origin-destination matrix • Passenger auto origin-destination matrix	Daily numbers (24 hour) of passenger vehicles and trucks on model network links

* Version 7 of FLSWM discontinued the visitor model that was present in version 6 of the model.

Table 21 shows that the final products of FLSWM are 24-hour link traffic volumes, which cannot be used to effectively evaluate projects intended for congestion relief or for emission estimation. In addition, variables for trip generation (i.e., population, households by sizes and auto ownership, and employments) are insensitive to travel behavior shift with respects to age and income levels. The mode choice model for short distance trips only removes a small portion of the origin-destination flows as transit trips without considering non-motorized trips. The most significant limitation of version 7 of FLSWN is the lack of a visitor model. It is worth noting that a visitor model that produces visitor trips of both in-state and out-of-state visitors to Florida, but the visitor model is discontinued in version 7 due to lack of new data for calibration.

4.4.2 Potential Model Modifications and Enhancements

Considering the planning issues and goals of the FTP and the modeling capabilities needed to address those planning issues, Table 22 presents potential model enhancements of the FLSWM based on its current capabilities.

To model the travel demand impacts of smart growth developments, trip reduction elasticities had been developed (Cervero, 2006) that can be multiplied by to trip production to reflect the number of trips reduced due to higher employment-to-household ratio of a TAZ (i.e., mixed-use developments encourage walking trips to replace auto for shopping or recreational trips within the same TAZ). Cervero (2006) documented several other approaches that can be used to model smart growth travel demand impacts.

Evacuation demand modeling is a complex problem that involves a large amount of data and assumptions specific to the evacuation event (Murray-Tuite and Wolshon, 2013). Trip generation, distribution, and mode choices for evacuation demand modeling are based on assumptions and modeling processes that are different from typical passenger travel demand modeling. Dynamic traffic assignment and/or traffic simulation, instead of static user equilibrium assignment commonly used for travel demand modeling, are used to load the evacuee origin-destination matrix onto the model network (Murray-Tuite and Wolshon, 2013). Typical travel demand model elements that can support evacuation demand modeling are the TAZs and the model network with their built-in population data and link attributes. Because the TAZs and model network of FLSWM cover the entire U.S. for the purpose of freight flow modeling, extraction of specific TAZs and a model network pertinent to the evacuation event may need to be performed before proceeding with evacuation modeling. Carrying a large number of excessive TAZs and network links can significantly reduce the processing speed for the model. The model network may also need to be augmented with additional data required by a dynamic traffic assignment algorithm and/or traffic simulation.

The emergence of ACES mobility options also points to the need for an activity-based approach that is able to capture the shifts in travel preferences and choices by demographic segments and reflect the impacts on trip generation, mode choice, trip lengths, and land use in the long run.

Table 22 Model Requirement, FLSWM Limitations, and Potential Enhancements

Travel Model Capabilities Required for FTP	FLSWM Capability Limitations	Potential Model Modifications and Enhancements
Reflect the effects of ages, races/ethnicities and income levels on trip generation rates and mode choices	Trip generation uses only population, household, and employment variables.	• Estimate trip rates and mode choices by ages, races/ethnicities, and income levels by TAZs. • Include these variables in trip generation and mode choices. • Replace auto occupancy procedure with a mode choice model. • Include these variables in auto-ownership model to reflect potential behavior shifts associated with different demographic segments.
Reflect traffic impacts of projects developed with Smart Growth policies.	• Trip generation process does not differentiate trip rate difference between high- from low-density TAZs. No differentiation on employment/households ratio either. • No non-motorized modes.	• Modify trip production component with elasticities of a TAZ based on its employment/household ratio. • Incorporate non-motorized modes in mode choice models. • Alternatively, develop a destination choice model to reflect the impacts of accessibility on travel choices.
Produce congested peak hour traffic volumes and speeds with capacity-sensitive traffic assignment methods for congestion and emission analyses	Produce 24-hour vehicle volumes without peak hour differentiation.	• Add a peak hour factoring process and apply a capacity-sensitive traffic assignment method to predict congested peak hour volumes and speeds. • Alternatively, develop a time-of-day choice model in the long run.
Capture the effect of ACES vehicles on changes in trip generation rates, trip lengths, share of trips by automobiles vs. other modes, and vehicular emissions.	• Effects can be estimated by FLSWM with simple assumptions about changes in trip TAZ terminal time, friction factors, and % automobile trip increase. • Model's final product of 24-hour vehicle volumes has limited value for operation level of service and emission analysis.	• Add an auto ownership or vehicle availability model to capture adoption of ACES vehicles. • Transition to activity-based approach to reflect individual choices by individual and household attributes. • Incorporate shared mobility options in the mode choice model. • Add a destination choice model to reflect the impacts on trip lengths.
Predict shares of all modes relevant for the context of studies	No non-motorized modes	Incorporate non-motorized modes and other relevant modes in mode choice models.
Predict long-distance (>50 mils) business and visitor trips	Model LDB trips but no visitor model	Develop a new visitor model or re-calibrate the version 6 visitor model with appropriate data.

Table 21, continued

Travel Model Capabilities Required for FTP	FLSWM Capability Limitations	Potential Model Modifications and Enhancements
Predict shares of modes (e.g., air, rail, automobiles) for long-distance trips	Model LDB mode choices, but no long-distance visitor trips.	Develop a visitor model with mode choices for short and long-distance trips.
Support evacuation modeling with model TAZs and network.	Model network and TAZs cover the entire U.S. for freight flow modeling. Excessive number of TAZs and network links can prolong model processing time	Extract only portion of the TAZs and the model network that are pertinent to the evacuation area under consideration.

4.5 Summaries

We reviewed the latest Florida Transportation Plan Vision Element to identify specific goals that are to be accomplished for Florida's future transportation. We identified specific transportation issues that need to be addressed in meeting the goals. Based on these issues, we identified specific model capabilities that are required for the model to produce results that can be used to evaluate attainment of the goals. Technical specification of version 7 of FLSWM were then examined to identify limitation of FLSWM in meeting these requirements. The most significant limitation of FLSWM is the complete lack consideration for visitor trips in the modeling process. By producing loaded network with 24-hour traffic volumes, FLSWM is also limited in its effective for evaluating projects that deal with congestion relief or emission reduction. To fully address the impacts of shifting demographics, changing travel behavior and potential implications of ACES, transition to an activity-based approach would be necessary. Next step of this project is to identify the best modeling techniques and data for modifications and enhancements for FLSWM.

5 RECOMMENDATIONS

Based on our examination of current FLSWM features and limitations (Chapter 3), capability improvements and enhancements needed for FLSWM to address the goals of the latest Florida Transportation Plan (FTP) (FDOT, 2020c) are summarized in Chapter 4. This chapter focuses on recommendations for specific components in the FLSWM.

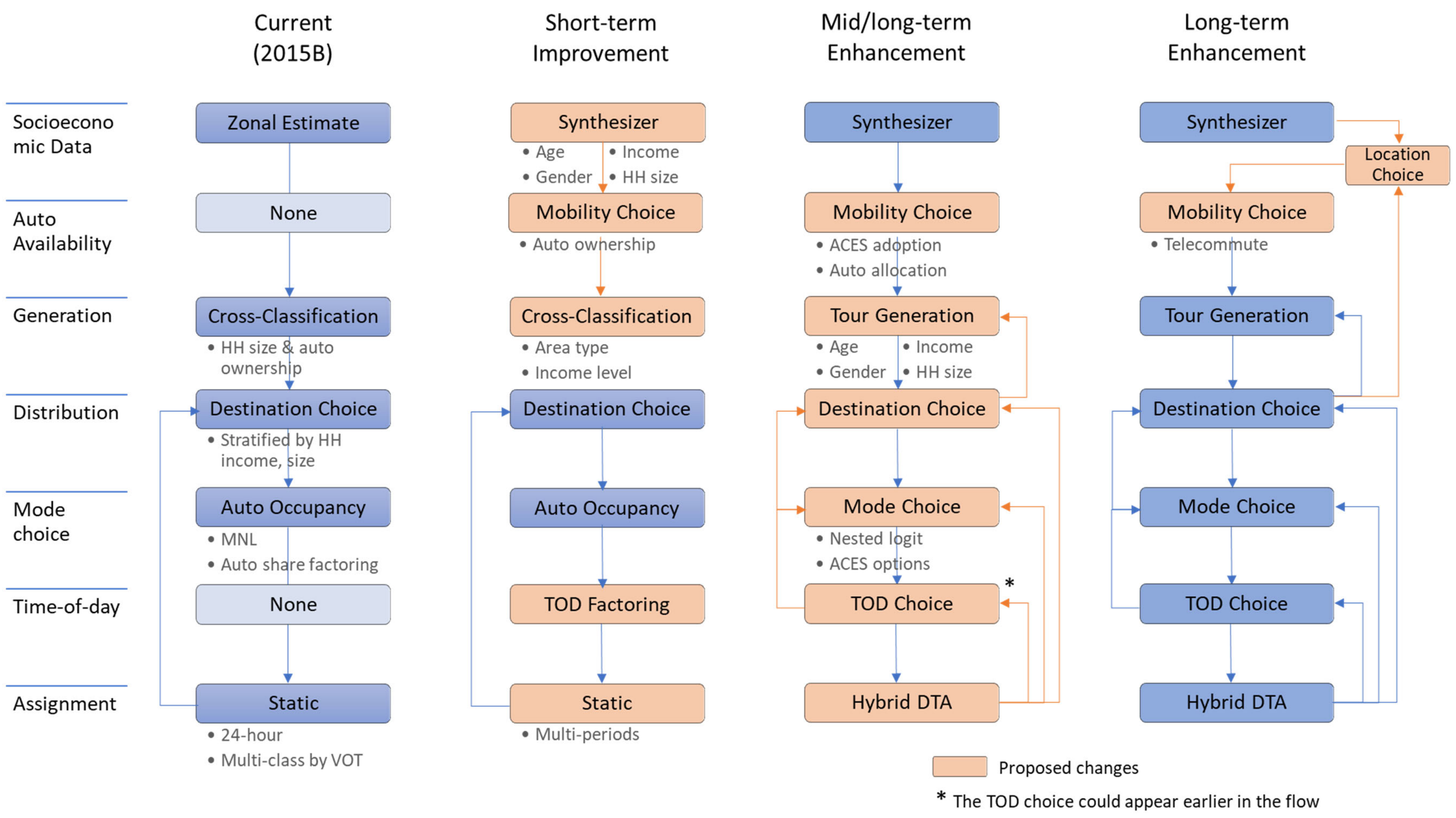
5.1 Short-Distance Passenger Travel

Figure 27 illustrates incremental improvements and enhancements for the FLSWM to address the goals of the FTP. Depends on the complexity of the improvements and the associated data and resources needed, the recommendations are grouped into short-term, mid/long-term, and long-term stages. The current implementation of the model is presented at the left-hand side, while the incremental improvements by stage are presented on the right.

In the short-term, the trip-based approach will be maintained. Modifications should focus on the most urgent needs, including time-of-day factoring that split daily trip tables into multiple periods which enables traffic assignment of peak periods. Peak hour traffic prediction is critical for evaluation of the state's increasing adoption of new technologies that aim to improve transportation efficiency and reliability. Additional modification could consider expanding the capacity of the cross-classification model for trip generation by including additional stratifications such as area type or household income.

In the mid/long-term, a transition to activity-based model (ABM) can be staged given resources available. Modeling capabilities required to meet FTA goals can be accomplished with ABMs better than trip-based models. Detailed behavioral responses to emerging technologies and mobility options by individual and household characteristics such as age, gender and income levels can be much better reflected through the ABM approach, which render the model more sensitive and useful in evaluating various policies, strategies and programs. Through a population synthesizer, which simulates a population with detailed characteristics based on US Census data, a variety of variables can be included in the subsequent choice models. A mobility choice component would be needed to address the adoption of vehicle technologies and mobility services, which would be critical in the era of ACES. In addition, dynamic traffic assignment or traffic microsimulation can produce hour-by-hour traffic volumes that can effectively facilitate evaluation of efficiency-oriented policies and technologies.

Longer-term enhancement may consider location choices for home, work and school and reflect the connection between transportation accessibility and land use. Additional mobility choice component, such as telecommuting adoption, can also be beneficial and reflect potential trend in telecommunications and the impacts on travel demand.



* The TOD choice could appear earlier in the flow

Figure 27 **Recommended Enhancements for Passenger Travel Demand Component**

Instead of completing the development of an activity-based statewide model at once, incremental implementation to update components of the existing model may be a better approach. This approach spreads the cost over several years and enables subsequent development to be adjusted or postponed according to up-to-date progress and/or funding availability. For the state of Florida to transition to activity-based statewide model, Maryland's experience may be followed. Maryland's MSTM 2 was developed with such an incremental approach (NASEM, 2017; Zhang, 2018).

It is noted that SERPM 8, the activity-based MPO model for the three most populated counties in Florida (i.e., Miami-Dade, Broward, Palm Beach) was completed and released in 2020 (FSUTMSOnline, 2020). The three counties covered by SERPM 8 account for approximately 28% of Florida's population. An activity-based statewide model for Florida can thus be based on SERPM 8, re-using much of the model resources available to reduce development cost. In addition, the Northeast Regional Planning Model Activity-Based (NERPMAB 2), which is the MPO travel demand model covering the Jacksonville metropolitan area, was also released in 2020 (FSUTMSOnline, 2020). Integrating data from both models for an activity-based statewide model can further reduce model development cost.

5.2 Long-Distance Passenger Travel

5.2.1 Short-Term Improvement

5.2.1.1 Visitor Travel

Visitor travel to Florida is an important component of the state's overall economy. Accounting for visitor trips in FLSWM is important for accurate evaluation of economic trends, policies, and infrastructure investments that may affect tourism in Florida. Currently, the trip-based visitor model of FLSWM is being updated with new data. It is expected that the visitor model will be integrated with FLSWM after update is completed.

5.2.1.2 Long-Distance Business Travel

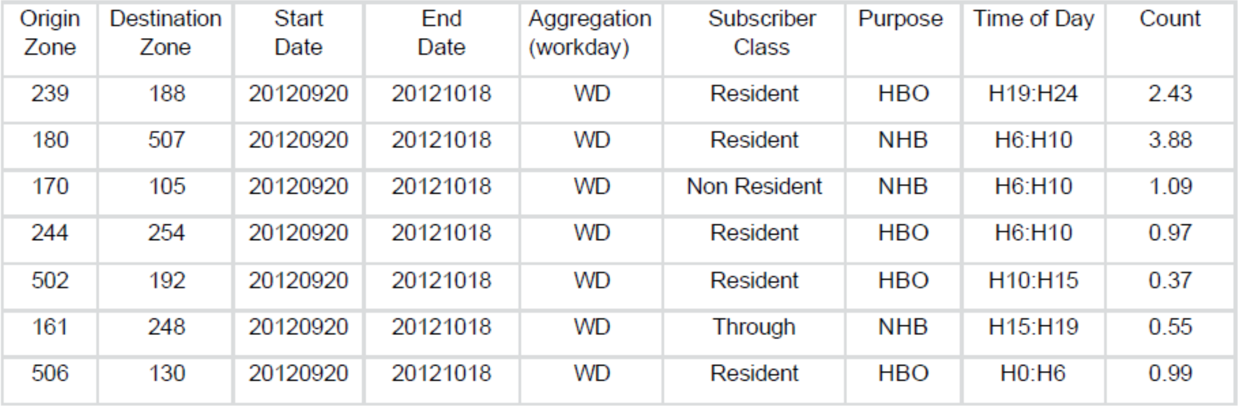
It was identified after scenario analyses with FLSWM that long-distance business (LDB) trips were incorrectly limited to approximately 225 miles in distance by LDB gravity model friction factors that have an upper travel time limit of 180 minutes. For short-term improvement that maintains FLSWM's existing trip-based model structure, two general options are available for correcting the error with LDB trips. First, the friction factors of the existing LDB gravity model can be recalibrated with upper travel time limit longer than 180 minutes. The other option is to replace the LDB gravity model with a destination choice model like the one used for short distance home-based trips.

The real challenge with either recalibrating the gravity model or developing a new destination choice model is the lack of appropriate data, because long-distance travel activities are rarely captured in household travel surveys (NASEM, 2017). Currently, only California, Colorado, and

Ohio had conducted separate long-distance travel surveys that were used for development of their statewide models (Outwater and Bradley, 2018). The American Travel Survey, conducted in 1995, is the only nationwide long-distance travel survey in the United States (BTS, 2019). The National Household Travel Survey (NHTS) conducted small-scale add-ons about long-distance travel in 2001 (BTS, 2017). Development and calibration of passenger travel demand models using the NHTS add-on data have been limited by the small sample size (Outwater and Bradley, 2018).

In recent years, O-D data derived from cellphone data have been used for various tasks involved in transportation planning (Hard et al, 2016). Prior to 2017, mobile-based O-D products were exclusively derived from cellphone usage records. Information available from a mobile-based O-D matrix ranges from trip origin, destination of trip, trip purposes, home zones, day of the week, time of day, and counts presented in person-trips, extrapolated to represent movement of the entire population (Hard et al, 2016). Table 23 shows an example of mobile-based O-D matrix.

Table 23 An Example of Mobile-Based O-D Matrix



Origin Zone	Destination Zone	Start Date	End Date	Aggregation (workday)	Subscriber Class	Purpose	Time of Day	Count
239	188	20120920	20121018	WD	Resident	HBO	H19:H24	2.43
180	507	20120920	20121018	WD	Resident	NHB	H6:H10	3.88
170	105	20120920	20121018	WD	Non Resident	NHB	H6:H10	1.09
244	254	20120920	20121018	WD	Resident	HBO	H6:H10	0.97
502	192	20120920	20121018	WD	Resident	HBO	H10:H15	0.37
161	248	20120920	20121018	WD	Through	NHB	H15:H19	0.55
506	130	20120920	20121018	WD	Resident	HBO	H0:H6	0.99

(Source: Hard et al., 2016)

For short term improvement of FLSWM's long-distance passenger model, it appears that purchasing mobile-based O-D data is the most economical approach for calibrating existing LDB gravity model or developing a new destination choice model. According to Schiffer (2015), the cost for obtaining these data is relatively inexpensive when compared to other data products. Mostly importantly, there is no long-distance travel survey available for the state of Florida. Compared with the potential high cost of conducting a long-distance travel survey capable of representing the population in Florida, an O-D matrix derived from cellphone data is currently the most viable source of data for improvement of the long-distance passenger travel component of FLSWM.

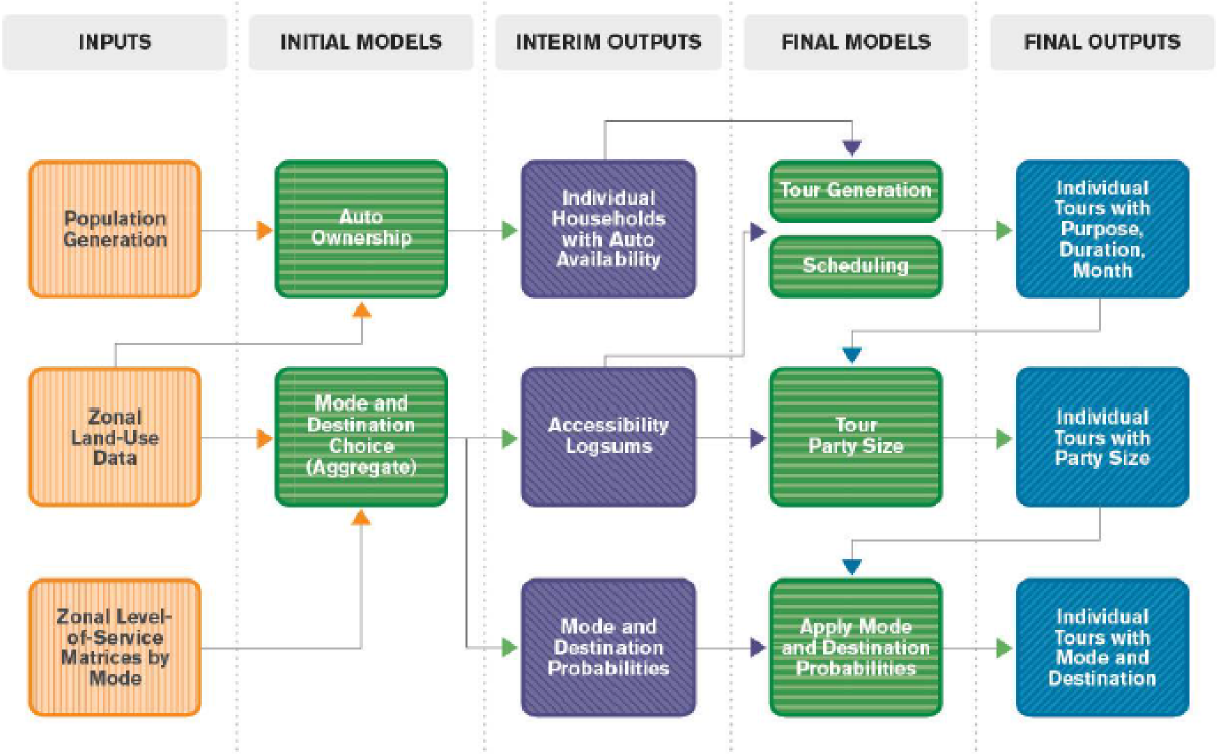
Regarding the options of either calibrating the existing gravity model or developing a destination choice model for LDB trips, either option has pros and cons. Keeping the existing LDB gravity model saves the cost for redeveloping a new model. However, the mathematical formulation of a gravity model cannot reasonably reflect trip interchanges between two large metropolitan areas separated by a long distance (NASEM, 2017). For example, there is a sizable number of daily intercity trips between Miami and Orlando, which are separated by over 200 miles. But it is difficult to calibrate the LDB gravity model to the right number of trips between Miami and Orlando, because the distance decay function of the gravity model tends to discount trip interchange by distance much more than by the magnitudes of attraction (e.g., population and/or employment) at the destinations. Thus, small cities closer to Orlando than Miami tend to be distributed with more LDB rips than Miami, which is the largest employment hub in Florida. On the other hand, developing a destination choice model for LDB trips requires development cost for a new model. However, destination choice model can be built to reflect long-distance trip interchanges better than gravity models (NASEM, 2017).

5.2.2 Mid/Long-Term Enhancement

5.2.2.1 National Long-Distance Passenger Travel Model

For mid/long-term enhancement of FLSWM, transitioning of the model structure from trip-based to activity-based is recommended for short distance passenger travel. With the transition, FLSWM's existing trip-based visitor and LDB models should also be replaced with activity-based models built upon the same Florida synthetic population used to model short-distance passenger travel. The national long-distance passenger travel demand model (Outwater and Bradley, 2018) developed for the Federal Highway Administration (FHWA) is an activity-based model that can be integrated with FLSWM to model long distance visitor and business trip. The model, known as rJourney, is a microsimulation of long-distance passenger travel activities including both visiting and business purposes that occur in a single year for all households in the United States (i.e., 117 million households and 309 million people based on the 2010 Census). The simulated long-distance tours (i.e., each tour is a series of long-distance stops serving various activity needs) include work-related (i.e., commute and business) and nonwork travel (i.e., visiting, personal business, and leisure). The definition of a long-distance tour used in rJourney is at least 50 miles, which is derived from the definition used by the National Household Travel Survey long-distance add-on (BTS, 2020a). The simulated long-distance tours in rJourney are distinguished by purposes (i.e., commute, business, visiting, personal business, and leisure). Thus, rJourney can cover the two types of long-distance trips (i.e., long-distance business and visitor trips) modeled by FLSWM.

rJourney is implemented as an application for desktop computers running the Microsoft Windows operating system with at least 4 GB of RAM and 10 GB of free disk space (Outwater, Bradley, Gore, and Oak, 2018). rJourney was written and compiled into a desktop executable application with the software Delphi (Pascal), which has the advantage of fast run times (Outwater, Bradley, Gore, and Oak, 2018). It is expected that integration of rJourney with FLSWM for continuous model run will require one-time alteration and recompilation of rJourney source code. Figure 28 shows the structure of the long-distance passenger travel demand model framework developed for FHWA.



(Source: Outwater and Bradley, 2018)

Figure 28 National Long-Distance Passenger Travel Demand Modeling System

Table 24 National Long-Distance Passenger Travel Model Data Sources

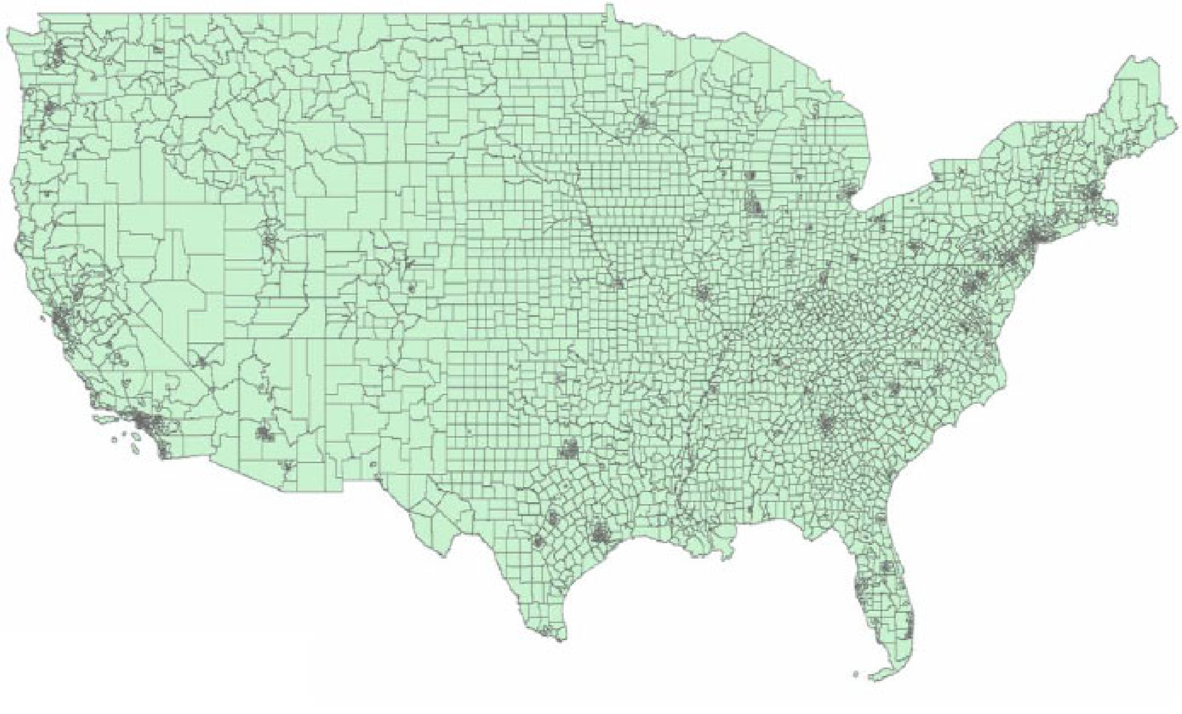
Data Product	Year	Source	Input	Estimation	Calibration	Validation	Comment
Zone System	2013	Census	Yes	No	No	No	Created by Arizona State University
Road System	2011	FHWA	Yes	No	No	No	Centroid connectors added
Toll Facilities	2016	FHWA	Yes	No	No	No	Toll facilities identified; tolls added
Rail System	2011	Amtrak	Yes	No	No	No	Access links added; GTFS data imported
Rail Fares	2004	Amtrak	Yes	No	No	No	Data factored to 2012 levels
Air System	2012	BTS	Yes	No	No	No	Airport connectors added
Bus System	2015	Bus Service Providers	Yes	No	No	No	Compiled from online schedules
Demographics	2010	Census	Yes	No	Yes	Yes	2010 PUMS and 2007-2011 ACS
Employment Data	2010	Census Bureau of Labor Statistics	Yes	No	No	No	Compiled from Census LEHD and BLS QCEW
Land Use Data	2010	Census	Yes	No	No	No	N/A
Park Data	2012	National Park Service	Yes	No	No	No	TomTom and ESRI data used to supplement NPS
Enrollment Data	2011	National Center for Education	Yes	No	No	No	N/A
Origin-Destination Data	2011	FHWA	No	No	No	Yes	Traveler Analysis Framework Interpolated from 2008 & 2040
Bus Ridership	2014	FHWA	No	No	No	Yes	Intercity Bus Ridership project
American Travel Survey	1995	BTS	No	Yes	No	No	12-month survey of long-distance travel in the U.S.
National Household Travel Survey	2001	FHWA	No	Yes	Yes	Yes	4-week survey of long-distance travel in the U.S.
California Household Travel Survey	2012	California DOT	No	Yes	Yes	No	8-week survey of long-distance travel in California
Colorado Front Range Travel Survey	2010	Colorado MPOs	No	No	Yes	No	2-week survey of long-distance travel in eastern Colorado
Ohio Household Travel Survey	2003	Ohio DOT	No	Yes	Yes	No	2-week survey of long-distance travel in Ohio
Traffic Counts	2007	FHWA	No	No	No	Yes	HPMS added to road system network
Vehicle Miles Traveled	2013	FHWA	No	No	No	Yes	Rural vehicle miles from the Highway Statistics Manual

(Source: Outwater and Bradley, 2018)

GTFS: General Transit Feed Specification; BTS: Bureau of Transportation Statistics; PUMS: Public Use Microdata Sample; ACS: American Community Survey; LEHD: Longitudinal Employer-Household Dynamics; BLS: Bureau of Labor Statistics; QCEW: Quarterly Census of Employment and Wages; NPS: National Park Service

To develop the models of long-distance passenger travel in the U.S., the study team of rJourney overcame the difficulty in lack of long-distance travel data by incorporating data from all available long-distance travel surveys in the U.S., including the American Travel Survey, National Household Travel Survey long-distance add-on, and data on long-distance travel form the California, Colorado, and Ohio household travel surveys. Table 24 shows the data used in rJourney development.

Household and population characteristics are synthesized for all census tracts in the United States by mathematically propagating the data in the Census Public Use Microdata Sample (PUMS) (U.S. Census, 2020a) such that the sums of the synthesized tract data marginally match the total numbers according to U.S. Census American Community Survey (U.S. Census Bureau, 2021). Zonal land use data for long-distance travel in rJourney are based on a new geographical construct, termed the National Use Model Area (NUMA), which is a composite representation of county boundaries in rural areas and U.S. Census Bureau Public Use Microdata Areas (PUMAs) (U.S. Census, 2020b) in urban areas (Outwater and Bradley, 2018). A total of 4,570 NUMAs are created for the entire United States. The NUMA geographic information systems (GIS) data was imported into TransCAD (Caliper, 2021). Figure 29 shows the extent of NUMA polygons in the 48 contiguous states.



(Source: Outwater and Bradley, 2018)

Figure 29 Final NUMAs for the 48 Contiguous States of United States

Data representing the multimodal (e.g., auto, rail, bus, and air) networks of the entire US are used to generate zonal level of service matrix (i.e., travel impedance) for each mode. For travel by automobiles, rJourney uses the National Highway Planning Network (NHPN) to estimate travel time, distance, and cost. The National Highway Planning Network (NHPN) is a GIS database containing geospatially referenced line features of over 450,000 miles of highways in the United States, including the National Highway System (NHS), the Eisenhower Interstate System, the Strategic Highway Network, and NHS Intermodal Connectors. The NHPN also covers roads classified as principal arterial and rural minor arterial (FHWA, 2018). The GIS data of NHPN were imported to TransCAD and connected with the centroids of NUMA polygons. Link travel time was computed as the length of the link divided by posted speed limit. NUMA-to-NUMA skims of travel time, distance, and generalized cost (i.e., highway skims) were computed using TransCAD.

Similar to the development of highway network data, GIS data of networks for bus, rail, and air were developed by the rJourney project team using data from available public sources. The bus network was identified as a subset of the road network by identifying links with intercity bus services provided in the United States (Outwater and Bradley, 2018). Rail network and service data were geocoded with the Generalized Transit Feed Specification (GTFS) data obtained from Amtrak (Outwater and Bradley, 2018). Network and service characteristics for air travel were developed from two databases from the U.S. Bureau of Transportation Statistics (BTS): the Airline On-Time Performance Data (BTS, 2021a) and the Airline Origin and Destination Survey (BTS, 2021b). GIS point representations of intercity bus terminals, rail stations, and airports were then connected to the centroids of NUMA polygons for calculations of NUMA-to-NUMA travel time, distance, and generalized cost skims of traveling by bus, rail, and air using TransCAD.

As shown in Figure 28, rJourney contains five separate modeling steps in the process of predicting passenger long-distance travel: Auto ownership, mode and destination choice, tour generation, scheduling, and tour party size.

Auto Ownership

The probability of a household owing a particular number of vehicles is predicted by a multinomial logit model with four choice options: zero cars, one car, two cars and three or more cars per household. The auto ownership model was estimated from four data sources: the long-distance travel records in the 2012–2013 California Statewide Travel Survey; the long-distance survey data in the 2001 NHTS New York state add-on sample; the long-distance survey data in the 2001 NHTS Wisconsin state add-on sample; and long-distance survey data in the 2003 Ohio Statewide Travel Survey.

Tour Generation

Tour generation includes two sequential models. The first model predicts the probability that a household takes a long-distance tour of a specific trip purpose within a period of one week. The second step models the probability of a household taking more than one long-distance tour in one week. Both models of tour generation are binary choice (i.e., no tour, or one tour for a given day), estimated with data from the California 2012–2013 Statewide long-distance survey. These two models jointly estimate the number of tours by purposes made by households in a particular month over one year.

Scheduling

After the number of long-distance tours in a year is determined for a household, scheduling of the tours is determined by a model that predicts how many nights the tour is made of, dividing into four categories:

1. 0 nights away,
2. 1–2 nights away,
3. 3–6 nights away, and
4. 7+ nights away.

The probability of a household deciding the number of nights away for a tour is predicted by a multinomial logit model. Five scheduling models were built, each of a tour purpose, including commute, business, visiting, leisure, and personal business.

Tour Party Size

The party size of a long-distance tour for a purpose is determined with a multinomial logit model with four choice options, including traveling alone, two, three, and four and more persons. Similar to models of tour scheduling, five party size models exist for the five tour purposes.

Mode and Destination Choice

Choices for Mode and destination of a long-distance tour are modeled as a nested choice. That is, the choice of mode for the tour depends on the destination chosen. Choices of destinations are the National Use Microdata Zones (NUMAs) that are at least 50 miles away from the tour origins. There are five destination choice models for the five trip purposes modeled, including commute, business, visit friends and relatives, leisure, and personal business. The modes available are: auto, air, rail, and bus. The mode and destination choice models were estimated with combined data from the same four long-distance surveys used for auto ownership model estimation (i.e., California, Ohio, New York and Wisconsin).

The travel impedance of a mode is measured in the rJourney models by a utility function known as the accessibility logsum. The tour generation and joint mode and destination models are supplemented with models for auto ownership, tour party size, and travel activity scheduling. Sequential applications of the five models of rJourney yield three output files: synthesized household file for the entire U.S.; tour file with purposes, durations, month, party size, destinations, and modes of long-distance tours made by the synthetic households; and matrices of origins and destinations (O-D) of all trips (i.e., tour segments by modes). The O-D matrices contain average daily long-distance trips by modes computed from the tour file that contains all long-distance tours made by all synthetic households. The average daily O-D matrices by modes are estimated by dividing the corresponding yearly matrices (i.e., aggregation of all tours) by a factor of 365.

5.2.2.2 Integration of rJourney with FLSWM

It is expected that the process of integrating rJourney with FLSWM will involve five data processing and analytical steps:

1. Combine FLSWM network with rJourney network.
2. Apply FLSWM population and employment variables and growth rates in rJourney's synthetic population and destination choice model for Florida.
3. Run rJourney with the combined network and FLSWM data.
4. Extract long-distance trips from-and-to Florida from national long-distance O-D Table.
5. Calibrate the model to mobile-based O-D and other available bus, rail, and air service data for Florida.

The first process involved in the integration of rJourney with FLSWM is the production of network skim on the highway network that combines the national highway network of rJourney with the network of FLSWM. The combined network will include the national model's NHPN highway network outside of Florida and more detailed FLSWM network inside and adjacent to Florida borders. Within Florida, the FLSWM traffic analysis zone centroid closest to a nearby NUMA will be used as the centroid for that NUMA. Highway skims, which are the basis for travel impedance measurement, for long-distance travel in the U.S. will then be created using the combined network. Travel impedance skims by bus, rail, and air can be estimated based on the original rJourney bus, rail and air networks.

The second process in the integration of FLSWM with rJourney is to enter FLSWM's socioeconomic data to the national model for the state of Florida, including demographic variables used in synthesizing population and employment variables used in destination choice modeling. The rJourney model will then be run with the travel skims calculated with the combined network and FLSWM socioeconomic data.

The final average daily origin-destination (O-D) matrices by modes produced by rJourney run will then be processed for long-distance passenger travel in-and-out of traffic analysis zones of FLSWM. For NUMAs inside and adjacent to Florida borders, corresponding O-D flows will be disaggregated into FLSWM analysis zones. For NUMAs farther away from Florida, O-D flows will be aggregated by NUMAs adjacent to each other. The long-distance passenger O-D matrices by modes will finally be combined with short-distance passenger and freight O-D matrices for combined traffic assignment onto the FLSWM network.

The long-distance travel activities on highways predicted by the integrated rJourney/FLSWM model should then be calibrated to passenger O-D matrices primarily by adjusting parameters in rJourney's component choice models. In particular, calibration involved adjustment of tour frequency and destination choice models. Calibration of long-distance travel activities to-and-from the NUMAs in Florida by bus, rail, and air should also be made with available service records of these modes, such as ticket sales or passenger counts.

5.3 Summaries

Based on the discussion of options for improving FLSWM, Table 25 summarizes our recommendations for specific tasks involved in each of the improvement options.

Table 25 Recommended Tasks for FLSWM Improvement

Improvement Timeline	Model Component	Recommended Tasks	Cost Estimation
Short-Term (Trip-Based Approach)	Short-Distance Passenger Travel	1. Include consideration of ages, races/ethnicities, and income levels in trip generation model. 2. Include consideration of ages and races/ethnicities in destination and mode choice models	The cost is likely a fraction of the total cost for the last major FLSWM update.
	Long-Distance Passenger	1. Obtain mobile-based O-D data for the state of Florida and areas adjacent to the state borders. 2. Subtract trips by commercial trucks and visitors from the O-D data. Extract LDB O-D data. 3. a. Recalibrate the LDB gravity model to the LDB O-D data, or b. Develop a LDB destination choice model and calibrate to the LDB O-D data	Total cost includes the cost for purchasing O-D data and consulting fee for processing the O-D data and calibration of trip distribution gravity model or development of LDB destination choice model.
	Time-of-Day Modeling	1. Develop time-of-day factors to divide daily trip tables into peak and non-peak periods. 2. Perform traffic assignment of the peak-period trip tables with a capacity-sensitive assignment method.	Cost is expected to be moderate as only individual task of time-of-day modeling is required.
Mid/Long-Term (Activity-Based Approach)	Short-Distance Passenger Travel	1. Develop the statewide activity-based model based on the Southeast Florida Regional Planning Model 8 (SERPM 8) model, reusing as much resources as technically appropriate. 2. Integrate modeling data and resources from the Northeast Regional Planning Model-Activity-Based 2 (NERPMAB 2).	Total cost may range between $1 million to several million dollars (NASEM, 2017)

Table 26, continued

Improvement Timeline	Model Component	Recommended Tasks	Cost Estimation
		3. Incrementally transition from trip-based to activity-based model by replacing one or several model components at a time.	
	Long-Distance Passenger Long-Distance Passenger	1. Combine FLSWM network with rJourney network. Insert detailed FLSWM network within Florida and maintain rJourney network for rest of US. 2. Apply FLSWM population and employment variables and growth rates in rJourney's synthetic population and destination choice model for Florida. 3. Run rJourney with the combined network and FLSWM data. 4. Extract long-distance trips from-and-to Florida from national long-distance O-D Table. 5. Calibrate the model to mobile-based O-D data for Florida.	Total cost may range between $1 million to several million dollars (NASEM, 2017)
Longer-Term Enhancement	Location and Mobility Choice Models	1. Develop models of location choices for home, work and school to reflect the connection between transportation accessibility and land use. 2. Develop mobility choice model to address adoption of options such as telecommuting and automated vehicles.	Cost is expected to be moderate as only individual task of location and mobility choice model development is required

Tasks involved and the associated costs for FLSWM to have the required capabilities depends on the modeling approach adopted for model improvements. For short-distance passenger travel modeling, short-term improvements are to be made for FLSWM's existing trip-based components. Thus, total cost associated with trip-based improvements to FLSWM is likely no more than the total cost paid for the last major update of FLSWM.

For long-distance passenger travel, it appears that purchasing O-D data from mobile-based is the most economical approach for calibrating existing LDB gravity model or developing a new destination choice model. According to Schiffer (2015), the cost for obtaining mobile O-D data is relatively inexpensive when compared to other data products. Mostly importantly, there is no long-distance travel survey available for the state of Florida. Compared with the potential high cost of conducting a long-distance travel survey capable of representing the population in Florida, mobile-based O-D data is currently the most viable data source for improvement of the long-distance passenger travel component of FLSWM.

Regarding the options of either calibrating the existing gravity model or developing a destination choice model for LDB trips, either option has pros and cons. Keeping the existing LDB gravity model saves the cost for redeveloping a new model. However, the mathematical formulation of a gravity model cannot reasonably reflect trip interchanges between two large metropolitan areas separated by a long distance (NASEM, 2017). For example, there is a sizable number of daily intercity trips between Miami and Orlando, which are separated by over 200 miles. But it is difficult to calibrate the LDB gravity model to the right number of trips between Miami and Orlando, because the distance decay function of the gravity model tends to discount trip interchange by distance much more than by the magnitudes of attraction (e.g., population and/or employment) at the destinations. Thus, small cities closer to Orlando than Miami tend to be distributed with more LDB rips than Miami, which is the largest employment hub in Florida. On the other hand, developing a destination choice model for LDB trips requires development cost for a new model. However, destination choice model can be built to reflect long-distance trip interchanges better than gravity models (NASEM, 2017).

The cost involved in developing a new activity-based statewide model for Florida is substantially higher than keeping the existing trip-based approach. Nevertheless, the activity-based approach is theoretically superior to trip-based models. The tour-based microsimulation framework can be implemented to address FTA goals more flexibly and accurately than trip-based models. As the population in Florida continues to age with more diverse socioeconomic backgrounds, an activity-based statewide model can reflect the effects of policies and investments decisions across different geographic and market segments in a way that cannot be achieved with trip-based models. The decision and timing of switching to the activity-based statewide model depends on goals of FDOT for FLSWM applications and funding resources available.

6 SUMMARIES

In this report, we discussed options for improvements and enhancements of FLSWM's capabilities required to address FTP goals. We then formulated our recommendations for improvement tasks and offered estimation of costs associated with different improvement options. Improving FLSWM with the existing trip-based approach involves mostly modification of current model components. For short distance passenger travel, we recommend adding variables of ages, races/ethnicities, and income levels to the model for capabilities required for address equity and accessibility. Time-of-day modeling is also recommended to address efficiency- and reliability-oriented policies and technologies. For long distance passenger travel, we recommend using mobile-based O-D data for either calibration of existing LDB gravity model or development of a LDB destination choice model, which costs more but is theoretically and functionally superior to the existing gravity model.

Developing a new activity-based statewide model for Florida is substantially more expensive than modifying the existing trip-based model. However, an activity-based model has better capabilities to address FTP goals better than existing model. The decision of switching to activity-based model depends on FDOT's expectations and goals for FLSWM applications and available funding sources. If the decision is made, we recommend developing the model based on SERPM 8 and NERPMAB 2 to save cost. It is also possible to complete the development of the activity-based model by replacing one or more model components at a time for better management of funding throughout the development process.

Regarding the timings for the improvement tasks, repairing the trip distribution model for LDB trips is consider the most urgent improvement needed in the short term, as well as adding time-of-day modeling capabilities. Transition to activity-based model that addresses ages, income levels, and other socioeconomic trends can be considered as a mid/long-term enhancement to take advantage of continuous development of activity-based MPO models in the state. For longer term enhancement, we recommend adding to FLSWM models of location choices for homes, workplaces, and schools and mobility choices of telecommuting and automated vehicles.

After the recommended improvements and enhancements of FLSWM are completed, FLSWM will then have the technical capabilities matching all the MPO models in the state of Florida. It will then be theoretically possible for FLSWM to be adapted for travel demand modeling involving the state as well as all MPOs in the state. It is noted that currently 77% of MPOs in the United States with populations greater than one million develop and operate travel demand models with limited interaction with respective statewide models (TRB, 2007). The lack of consistency between a statewide model and all MPO models in the state can lead to recommendations and adoption of statewide or regional investments and policies that do not address the common interest of the entire state (Boyles et al., 2017). In an ideal scenario, for which a statewide model is a complete representation of all MPO models in the state in terms of geospatial resolution and technical capabilities, one might imagine that all state and MPO staff maintain and operate one travel demand model in a strategic fashion, fostering consistency of planning efforts at the statewide and regional levels as well as reducing the financial resources required for model development and maintenance. With ever increasing computing power and availability of data from cellphone providers and commercial services (e.g., Google), the vision of one travel demand model for all MPOs in a state is no longer an issue of technical limitations. The difficulty in achieving the vision realistically lies in the differences in agency priority, modeling needs, and forecasting and model updating timelines (Boyles et al., 2017). For the significant amount of financial resource that can be saved for travel demand modeling in the state as a whole, the issue of developing and maintaining a uniform travel demand model for the entire state of Florida should be discussed by all statewide and MPO planning staff once FLSWM match all MPO models in technical capabilities.

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