

Use of the Florida Statewide Model



report

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date

April 30, 2018



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1.0 Abstract

The Florida Statewide Model (FLSWM) is a transportation planning tool primarily designed for two categories of use cases: (1) to provide transportation forecasts in study areas that are outside the boundary of any existing MPO or regional model (e.g. rural areas), and (2) to provide forecasts for study areas that cross between multiple MPO or regional models, or between MPO or regional models and otherwise un-modeled rural areas.

This document is designed to give planners and policy makers some insight into the development and proper application of the Statewide Model. It serves as a companion to the Model Users Guide for the passenger and freight components of the model, which provides detailed technical information about the actual operation of the model, as well as the Model Validation Report, which provides a more complete statistical analysis of the results. The document provides a review of the model framework, the inputs and outputs of the model, the development process, and a discussion of the appropriate uses of the model, plus a checklist to consider before employing the FLSWM in any application. Given the need to be judicious about prioritizing among competing demands for limited resources, there is a need to have an analytical tool like the FLSWM that helps with the resource allocation. However, inherent in any forecasting process, there are uncertainties associated with it and this document lays out a process for quantifying this uncertainty so that policy makers can prioritize resource allocation while mitigating the impacts of different outcomes.

2.0 Model Framework

The **Florida Statewide Model** (FLSWM) is a transportation planning tool primarily designed for two categories of use cases: (1) to provide transportation forecasts in study areas that are outside the boundary of any existing MPO or regional model (e.g. rural areas), and (2) to provide forecasts for study areas that cross between multiple MPO or regional models, or between MPO or regional models and otherwise un-modeled rural areas.

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The basic framework of the **passenger travel** components of the FLSWM is built to represent automobile travel within, into, and out of the state of Florida. The framework resembles that of a four-step model, as has been used in many of Florida's MPO and regional models. The four steps include:

1. Trip generation (how many trips),
2. Trip distribution (where do they go),
3. Mode choice (by which means of transport), and
4. Network assignment (by what route).

As implemented in the FLSWM, the mode choice step is essentially skipped in the passenger model, because only travel by automobile is modeled for passengers. By limiting this model to just automobile travel, the complexity of the model is greatly reduced compared against a model that would more fully encapsulate multi-modal transportation. This limitation is reasonable given the typical scope of applications of the FLSWM, as will be discussed further below. Most saliently, almost all usage of transit services in Florida occurs *within* metropolitan areas and regions that have more detailed local transportation forecasting models. Since this model is designed for applications outside or between such areas, accounting for such travel becomes substantially less important.

The **freight model**, called FreightSIM, is substantially different from the passenger model for a variety of reasons, not the least of which is that freight transport is substantially more variable in quantity and regularity than passenger transport. While households tend to produce travel in similar ways (e.g. with daily commutes to work and school, less frequent but regular trips for shopping, etc.), different firms of similar size can generate wildly different quantities of freight. For instance, a software firm can employ hundreds of people and generate millions of dollars in sales while generating negligible freight traffic, while an orange juice processor of the same size might generate many thousands of long haul rail car trips per year. This heterogeneity motivates a different modeling structure. In addition, freight trips are often long haul trips, so the freight model is based on a national scale model of freight activity plus a sample of international activity, unlike the passenger model, which is limited to in-state travel. This wide scope is necessary because many Florida firms ship products directly to and from far flung destinations, and the mode of transportation will vary depending on the unique characteristics of the product and geography.

The passenger and freight models come together in the network assignment component, where cars and trucks are assigned to particular routes on the highway network. The assignments for each are made simultaneously, so as to more accurately represent the impact each has on traffic congestion that affects both.

3.0 Model Development

3.1 Model Input Data

The various components of the travel models rely on a variety of data. These data are discussed briefly here, and in greater detail in *Appendix A: Data Used in Modeling*.

3.1.1 Zone System Geography and Demographics

The most basic data is the **zone system**, which defines the level of spatial detail that is available; the FLSWM is based on 8,518 travel analysis zones (TAZs) within the state, plus a few hundred external zones to represent locations outside the state. For each zone in Florida, a variety of socio-economic (SE) data is tabulated, both for the base year as well as any forecast years. For passenger travel, only the travel actually within the state of Florida is modeled, and trips that enter or leave the state are modeled only from the in-state origin to the state line, or from the state line to the in-state destination. Freight travel is handled differently, as the final destination for freight trips plays an important role in mode choice, even when the destination is far from Florida. Thus the freight model has zones that span the globe, although with decreasing resolution as the distance from Florida increases.

3.1.2 Highway Network

Connecting zones together is a representation of the transportation **network** within and around the state. While the actual Florida transportation system contains myriad modal choices for both passengers and freight (automobiles, trains, buses, etc.), for passenger travel the statewide model focuses exclusively on cars using highways and major roads. No attempt is made to include all roadways in the state, in large part because of the modest granularity of the travel analysis zones. Including all minor roads is unnecessary, because there is insufficient detail in the TAZs to support assigning traffic counts to minor streets. Details about the included roads (e.g. speed limit, number of lanes, tolls, etc.) are also attached to the road network for the base year as well as any forecast scenario years, although in many cases the attributes will not change over time. Additionally, roads can be flagged to be added or removed from the network for future scenarios, and for membership in a variety of categories for summary analysis (e.g. by District, County, or Corridor). A subset of network links also have traffic counts, based on observed data collected on the link, used in part to calibrate and validate the model.

For each road segment represented as a network link, a **volume-delay function** is determined based on the computed link capacity and the facility type (e.g., interstate, divided arterial, collector, etc.) and area type (rural, non-rural). In general, delays on rural roads accrue more slowly as volume approaches capacity, and in urban areas major highways suffer lesser delays (as a percentage of free flow travel time) as volumes approach capacity, but then degrade more quickly if volumes actually exceed roadway capacity.

3.1.3 Special Generators

In a few cases, the travel demand to or from a particular location is not well explained by the various data outlined above. These locations are handled by designating particular facilities as **special generators**, which attract passenger trips at rates greater than would be modeled based purely on population and employment factors. For the FLSWM, these special generators include airports, seaports, and Disney theme parks. Trip

generation rates for each special generator are created through a separate individualized study of the traffic associated with the particular facility.

3.1.4 Freight Data

The freight model relies on a variety of additional **freight-centric data sources**: multimodal transfer and access points for non-highway modes, and economic activity data including commodity production and consumption, freight flows, and employment. Unlike the passenger model, the freight model includes a modes and transfers component that predicts the usage of four primary modes (road, rail, air, and waterway) and transfer locations for shipments with multi-stop supply chains. This requires a representation of the rail, air, and waterway networks, and a set of transfer nodes that links the various modal networks together and allows for intermodal transfers. Network connections for these modes need not account for capacity or geometry, but instead merely represent the distance (cost) and connectivity of the network.

3.2 Model Outputs

The FLSWM provides a variety of outputs, although the principal output is a measure of highway traffic: the **congested speed** on each modeled roadway section, as well as the **volume** of traffic (vehicles per hour) segregated by vehicle type: autos (internal to Florida and external trips), and trucks (segregated into light, medium, and heavy). These two output factors are closely linked through the volume-delay functions, discussed above under *Highway Network* inputs. The speed and volume measures can be combined with network geometry attributes to calculate vehicle miles traveled (VMT), and vehicle hours traveled (VHT).

These outputs can be displayed graphically, to generate maps of travel and delay, and changes thereto that arise over time or as the result of different scenarios, that can aid in policy making. The outputs can also be post-processed using a variety of other tools to generate measures of economic impact, environmental justice, pollution and air quality, and other related measures, as discussed below under *Appropriate Uses of Model*.

In addition to the standard outputs, the FLSWM provides through the Cube software the capability to conduct **Select Link Analysis**. For a selection of any roadway link in the model, this tool allows the analyst to identify the origin and destination for all traffic (by type, as above) using the selected link. This kind of analysis is especially useful for initial consideration of projects that impact a particular highway facility, so that the scope of direct impacts (i.e., travel time savings gained by existing facility users) can easily be visualized and measured.

3.3 The Model Development Process

The FLSWM has been developed using a traditional approach for travel forecasting models, including estimation or assertion, calibration, and validation for each model component. *Estimation* involves statistical analysis of observed data to develop a mathematical model that describes the underlying processes with a reasonable amount of accuracy and detail (with “reasonable” being highly context sensitive). If data is not available to describe a particular process, a model can instead be *asserted*, where the mathematical structure of the model is simply created based on the modeler’s expectations, or copied from a different region. *Calibration* is the adjustment of model parameters to ensure that the resulting model reproduces base year results accurately. *Validation* is a check of the results of the application of a calibrated model, to ensure that results appear reasonable (both for base and forecast years), are consistent with other observed base year data, and show expected sensitivities to input data.

The model **estimation** process for the current FLSWM is generally based on the Florida Standard Urban Transportation Model (FSUTMS), although some steps are slightly modified. For example, the FLSWM model does not consider external-external trip (i.e., through trips) as the peninsular geography of the state makes such trips all but impossible.

For model **calibration and validation**, the FLSWM outputs were separated into passenger and freight components, to ensure each part provided reasonable and consistent results. The validation process was also undertaken at a variety of scopes: system-wide, district-wide, corridor, and country-wide level. The validation at the statewide scope relies on a statistical evaluation of the outputs across wide geographies, to ensure the model is behaving reasonably in aggregate. Analysis at the district level focuses on distinct regional variation: relatively stable results for northern rural areas, strong seasonal variation in urban southern areas, and exceptionally high visitor traffic around Orlando. Validation at narrower scopes such as the corridor level was also undertaken to ensure that more specific flows were behaving as expected, and that county level results did not show any unusual outlier results. An extensive report on the validation process and results is available separately.

4.0 Appropriate Uses of Model

The FLSWM is a versatile tool that is appropriate for a wide variety of applications, both for high level analysis at the statewide scope, as well as for more detailed evaluation of more localized transportation impacts. Many appropriate uses for the model are discussed in this section, although this document is not necessarily an exhaustive list of every reasonable use.

4.1 Strategic Policy Planning

A principal use of the Florida Statewide Model is for **strategic policy planning** in support of FDOT's mission to ensure economic prosperity and preserve the quality of Florida's environment and communities. The FLSWM can provide a window to see how planned transportation investments may achieve those goals in the years to come by generating forecasts for future years, especially to give some insight into how future population growth and economic development will likely impact the transportation system. The FLSWM can be used to support several strategic planning tasks: to calculate the capacity of infrastructure, e.g., how much delay will be expected on a particular highway segment; to estimate the financial and social viability of projects, e.g., using cost-benefit analysis and social impact assessments; and to calculate environmental impacts such as air pollution and noise. A variety of these planning applications are discussed below.

4.1.1 Project Prioritization

One important policy planning application that the FLSWM is very well suited for is **project prioritization**. The model can also be used to gauge the viability of various proposed transportation solutions, e.g. will adding lanes to a highway make congestion better (by increasing capacity for existing travelers), worse (by enticing new users), or just different (simply shifting a bottleneck further down the highway), and by how much. This can be used to compare the benefits of different projects that are competing for limited state resources. Using this information, along with an estimate of project costs and an understanding of policy goals and future funding streams, planners can allocate statewide resources most efficiently to preserve and enhance transportation infrastructure.

4.1.2 Risk Analysis

Another important approach for using the FLSWM for strategic planning is through **risk analysis**. This process involves varying the input data for future year scenarios across a range of reasonable forecasts, and measuring the variability in transportation impacts (congested travel times, link volumes, tolls collected, etc.). For example, by setting population growth forecasts at the top (and bottom) of the expected range of possible growth values (instead of at the single "most likely" value), forecasts for congestion can be expressed as a range of possible values, instead of as a single point estimate. This kind of risk analysis is important for transportation forecasting, not because of the uncertainty and imprecision in the model itself, but because of the uncertainty inherent in forecasting demographic trends and other model inputs.

4.1.3 Sketch Planning

The FLSWM can also serve as a valuable **sketch planning tool**, to provide a relatively quick and low effort method for evaluating the general impact of infrastructure investments. This impact can be evaluated both through the direct outputs from the FLSWM (e.g. what will the congestion delay on an existing highway be with and without a lane expansion) and through other measures derived from these outputs. Although the

level of detail in the existing model may be insufficient to carefully evaluate all the impacts of a project, it can provide a general “order of magnitude” picture of impacts. This can give planners an eye to project benefits and drawbacks very early on in the planning process, and help guide decisions on which projects should be considered more seriously, especially given the expense involved in developing a complete and sufficiently detailed travel forecast and environmental impact analysis.

4.1.4 *Economic Impact Analysis*

The outputs of the FLSWM can also be used as an input to other econometric models to conduct **economic impact analysis**. For example, an analysis can be done using the travel time outputs to evaluate the total amount of congestion-related delays in the network. This in turn contributes to savings for residents and especially on logistical costs to business. An economic forecasting model can be used to estimate the direct and follow-on competitiveness impacts of the proposed transportation investment on Florida’s economy, both in employment measures (e.g., n jobs created) and in income and productivity measures (e.g., an \$ x million benefit to the Gross State Product). Such an analysis typically would include only the long-term economic impacts, and not any short-term construction related jobs and impacts, which don’t appear explicitly in the FLSWM and need to be accounted for separately.

4.1.5 *Air Quality Modeling*

The Clean Air Act, as amended, establishes **national ambient air quality standards** (NAAQS) regulating a variety of pollutants. All non-attainment areas are required to assess air quality through the federal Motor Vehicle Emission Simulator (MOVES) program. Inputs to this assessment model are based on outputs from travel demand models such as the FLSWM. While all of Florida currently meets federal standards for emissions and greenhouse gases, additional emission requirements for capacity improvements may be required, and the FLSWM can support those efforts, especially in areas outside of those covered by regional models.

4.1.6 *Emergency Operations and Resiliency Planning*

The FLSWM can be useful in planning for **extreme events**, especially for long term implications arising out of such events. For example, the model can be used to consider the congestion impact on alternative roadways if a certain highway or group of highways is closed for a period of time. Recent years have had multiple instances of significant transportation disruptions that are both large scale (e.g. hurricanes) as well as smaller in scope but still acute (e.g. bridge collapse, industrial accidents) that can spontaneously close a segment of highway for weeks or months. Depending on the particular highway segment, a closure can have impacts hundreds of miles away (especially on freight traffic), which makes the FLSWM particularly useful for analyzing and understanding such eventualities.

4.1.7 *Automated and Connected Vehicle Planning*

The FLSWM can be used to begin to explore the impact of **automated and connected vehicles** on the transportation network. Although relatively little is known with confidence with about how automated vehicles will impact travel behavior, it is possible hypothesize about how such vehicles might change behaviors, and measure what kind of impact such a change would have on the transportation network. For example, under current technology, children younger than 15 years old can never travel in car on their own, but with a fully automated vehicle that becomes possible. This could result in entirely new mobility patterns for middle and high school students, and potentially a large increase in overall VMT, depending on how widespread the

adoption of such technology would become. It is certainly not clear what the likelihood is of such a scenario, but it may be useful to explore various possible futures to see what might happen by changing the inputs and assumptions in the FLSWM.

4.1.8 Toll Revenue Forecasting

The FLSWM could in theory be employed as a tool for forecasting **toll revenue** for roadways with tolls. Because it includes substantially all existing and likely all future toll road facilities, and forecasts vehicle volumes by vehicle type (passenger cars, plus 3 different categories of trucks), it is possible to generate an estimate of revenue generated from tolling facilities. This analysis could be undertaken both to evaluate the impact of general network transportation improvements on toll revenue (e.g. evaluating how an increase in the level of service on a parallel free highway might impact toll revenues) as well as the direct impacts of a change in tolling rates on tolling revenue (e.g. generating a measure of the price elasticity of demand for toll road usage).

However, it is *not recommended* to employ the FLSWM as currently constructed for forecasting toll revenue. In the current model, each toll collection facility has a separately determined conversion factor to convert the toll collected into equivalent travel minutes. This allow for a very well calibrated result on volumes at toll facilities, reflecting locally important factors in toll road usage that are not otherwise incorporated into the FLSWM. But a consequence of this is that these locally important factors become conflated with the general willingness to pay for toll facilities, making it difficult to reliably measure the price elasticity of demand on these facilities. Future enhancement to the FLSWM could address this problem, by incorporating more detailed data from surveys or time series observations to generate more stable estimates of conversion factors between tolls and equivalent minutes of travel time, and separate calibration factors to reflect locally important factors.

4.2 Urban and Regional Modeling Support

The FLSWM can also provide important support to urban and regional models. These models typically will provide a more detailed picture of the travel demands within the particular region, and generally will be preferred for analysis of travel principally contained within the region. However, the outputs of the FLSWM can still be useful to provide certain inputs to regional models.

4.2.1 External Travel

All urban and regional models in Florida rely in part on an **external travel** component, which models travel entering or exiting the modeling area (or both). The FLSWM can provide a measure of this external travel, as in most cases the trips that are “external” to a single regional model will still be substantially internal trips within the FLSWM. These trips (i.e., all traffic on highway segments entering or departing a regional model area) can be extracted from FLSWM outputs and provided as an input to the regional model.

4.2.2 Freight Components

Some less sophisticated urban or regional models may focus on passenger travel and may not contain a **freight model** that is as sophisticated as the freight components of the FLSWM. In these cases, it may be reasonable to use the relevant freight forecasts from the FLSWM in their entirety to provide the truck travel components in the urban or regional model, while using the passenger model results from the FLSWM only to provide other supplemental model support.

4.2.3 Model Validation and Reasonableness Checking

For urban and regional model components that are not drawn directly from the FLSWM, the results of the FLSWM can be used as a source of **external validation**. While more detailed forecasts from a separately constructed urban or regional model will not exactly match the results from the FLSWM, especially on lower classifications of roadways (e.g., arterials and collectors) the expectation is that traffic totals on major highways will be roughly similar, especially for base year conditions. While it is generally preferable to validate against “ground truth” observed traffic counts, the FLSWM can supplement counts by providing estimates for locations without observed counts, or where the observed counts appear to be erroneous (as count data can sometimes have substantial errors).

4.3 Sub-Area and Corridor Analysis

The Statewide Model can also be a useful foundation for analyzing individual **subareas and corridors** in detail. Depending on the location of a given subarea or corridor, the resources available to develop reasonable forecasts will vary. Corridors located substantially within the model coverage areas of one of the various Metropolitan Planning Organizations (MPOs) in Florida will probably best be modeled by that MPO’s travel demand models, and those models should be examined first to see if they provide a good solution. When analyzing a corridor within MPO boundaries, the overall performance of the MPO model should be reviewed to ensure that the model was adequately validated, followed by a more rigorous review of the corridor.

For corridors located in areas that **do not have an urban travel demand model**, or areas that cross over the modeling areas for multiple MPOs, the statewide model will provide a good foundation for analysis. In these instances, the area around the corridor should be reviewed to see if the zones and roadways provided in the statewide model provide sufficient detail for developing forecasts. If additional detail is needed, it is possible to update the network and zonal structure to a level of detail which will support the corridor analysis, by subdividing zones and adding highway links as appropriate. In many cases where the corridor crosses through multiple MPOs, the required additional detail may be readily available from the MPO-level model for that area. Otherwise, zones may need to be subdivided specifically for the relevant corridor study, in which case the modeler may refer to [A Recommended Approach to Delineating Traffic Analysis Zones in Florida](#).

In concert with increasing the detail of the model within the target subarea or corridor, it will often be desirable to **limit the geographic scope of analysis**, as very few transportation projects are likely to have transportation impacts across the state. For instance, highway improvements between Port St. Lucie and Sarasota are very unlikely to make any impact at all on transportation levels of service anywhere north of Orlando or south of Ft. Lauderdale. It is especially important to limit the scope of analysis when this is done in conjunction with adding enhanced zonal and network detail, as running such a detailed model without limiting the geographic scope might easily overwhelm the memory and processing power of the computer used for modeling. Limiting the scope of analysis to just a subarea can also greatly speed model run times, by avoiding spending computational resources on links and zones where there will be no meaningful impact, while preserving and enhancing detail and model sensitivity in the target area.

The geographic scope limitation is achieved by asserting that there are no travel impacts outside the limited model scope, and fixing travel that enters or exits the limited model area as “external” travel. If the scope of the subarea for a particular project is not obvious, running the full statewide model with just the existing level of detail (as may commonly be done early in any project for sketch planning purposes) can provide a guide for establishing the widest extent of the substantive impacts for any particular investment.

Another benefit of limiting the geographic scope of a corridor or subarea model is to **enhance calibration and validation**. The full statewide model is calibrated and validated to provide good results for the state as a whole, and for certain regions and corridors. However, it is not necessarily well calibrated to provide the best possible results for any particular subarea or corridor, even those that have been explicitly defined in the calibration and validation reports. By limiting the model to a particular subarea, it becomes easier to enhance the fit of the model by more precisely calibrating for the specific area under study.

Lastly, for more detailed corridor studies, there will be significant benefit in **enhancing the resolution and detail of the roadway network** to include many more streets than are currently represented in the statewide model. These smaller streets can sometimes absorb a notable share of short to medium distance trips (particularly those under 5 miles). This can be particularly important in reasonably congested areas, where lower capacity streets sometimes become residents' favorite "secret short cuts".

4.3.1 Detailed Sub-Area Analysis

In this section, we detail the steps to do a subarea or corridor analysis using the statewide model. First, the corridor or subarea in question need to be identified. One way to do that is to use a GIS related software to create a boundary of that corridor. Then this boundary shape needs to be overlaid on the statewide network to identify the network links that are within the boundary. Another way to do this is to use the ability of travel demand software to identify the boundary of the corridor. The external links outside the corridor/subarea also need to be identified.

It is possible that the statewide network may not have detailed roadways in the corridor in question. There are two ways to deal with this issue. One is to add detailed roadways in the statewide network. It may also require adding new zones to the statewide network. Adding new zones will require splitting up old zones and adding centroid connectors etc. These new zones need to have proper socio-economic data. The entire model needs to be run to get the final statewide trip table. This final trip table is used in the highway assignment process with the travel demand model's subarea extraction method. The extraction process will generate trip table consistent with the subarea. The other way is to run the subarea extraction using the statewide network as it is without adding detailed roadways. After subarea is extracted detailed roadways are then added to the subarea. However, one issue is that if additional zones need to be added, the subarea zones will need to be modified accordingly. As a result, subarea trip table extracted earlier also needs to be modified in order to be consistent with the updated subarea network.

Next step is to have counts in the roadways. It is very important to have as complete a coverage as possible with base year traffic counts in the corridor in question. Usually, corridor analysis requires peak hour or peak period counts. The goal is to adjust the subarea base year trip table such that estimated traffic during assignment process match with base year counts. This base year trip table adjustment process is known as Origin-Destination Matrix Estimation process (ODME). Any planning software has this capability and the next section details how to do it in Cube (the software platform for the Florida Statewide Model).

4.3.2 ODME Using Cube

First, a subarea is extracted in Cube according to the procedure described above. It is imperative to make sure that the subarea has all the required road networks. A corresponding subarea trip table is developed during the extraction process. Next, peak hour or peak period counts for the base year need to be added to the subarea roadways. If there is any turning movement data, it can also be used during ODME process. Cube's Analyst program will perform this activity. Usually several iterations are required for ODME until the

difference between estimated volumes and counts are within certain thresholds. Once this threshold is met, the trip table is considered to be a final table for the base year. This final table is then used in the subarea trip assignment process to create base year traffic flow and turn movements that can be analyzed for base year traffic analysis in the corridor.

For future year traffic analysis, first a future subarea raw trip table is derived using the future year statewide model. This subarea trip table is then adjusted based on the following formula:

$$\text{Future Year Adjusted Table} = \text{Future Year Raw Table} - \text{Base Year Raw table} + \text{Base Year ODME table}$$

This adjustment is done for every O-D pair of the trip table. However, some O-D pairs may have negative values due to this adjustment process. Those pairs should be considered to have zero trips for simplification purposes.

This future year adjusted subarea trip table is then used to assign on the subarea network. This will create future year traffic flows and turn movements that can be used for traffic analysis.

5.0 Risk Analysis Methodology for Quantifying the Uncertainty of Travel Demand Forecasts

All travel demand models, whether they are trip-based models or activity-based models, are abstractions of complex systems. The impacts of the abstractions should be understood and reflected in the forecasts produced by the model. In addition, future conditions that are either embedded as assumptions or are included as inputs into the model cannot be predicted with certainty. Most decision-makers rely on point forecasts, and thus, fail to recognize the uncertainties that accompany predicted outcomes.

The purpose of the risk analysis is to incorporate the uncertainty associated with model inputs and assumed travel behavior into the forecasting process. A risk analysis approach allows the analyst to express forecast results as probabilities of achieving different outcome levels. In order to develop a full range of possible forecasts, dozens of full model runs are used to estimate relationships between forecast revenue (toll or new transit systems) and ridership and select input variables (“meta-model”). The approach begins by identifying potential risk factors that could impact forecasts (e.g., potential changes in auto operating costs or the impact of new technologies such as autonomous vehicles). These factors are estimated using model variables, and the variables are systematically narrowed to the set of inputs that would have the highest combination of uncertainty and impact on the forecasts. The “meta-model” is coupled with researched distributions of the model inputs and used in a Monte Carlo simulation to develop a large number (10,000 to 50,000) of unique forecasts. From this simulation, probability distributions of total traffic or ridership or revenue are estimated.

5.1 Overview of the Risk Analysis Approach

An eight-step risk analysis approach is employed to forecast traffic as shown in Figure 5-1.

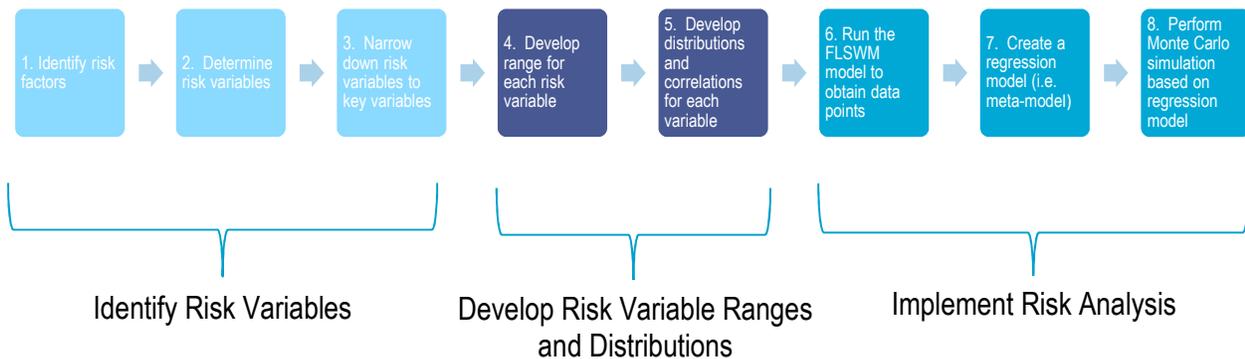


Figure 5-1 Eight-Step Risk Analysis Approach

The steps to identify the model assumptions are described below.

Step 1. Develop a list of possible risk factors to be considered for the revenue and ridership risk analysis

- Risk factors are defined as any circumstance, event, or influence that could result in the projected traffic deviating from its forecasted value;

- These risk factors are developed using either the consensus of a panel of experts or an evaluation of external and internal factors that can impact future travel demand and traffic.
- The identified risk factors may differ between forecast years.

Step 2. Identify risk variables for each risk factor

- Risk variables are actual variables and constants that can be adjusted in the FL Statewide Model. As an example, auto operating cost (i.e., cost, in dollars, per vehicle mile driven) is a risk variable that can be adjusted in the model. To address the possibility that fuel cost and fuel efficiency may be higher or lower than predicted, auto operating cost may be increased or reduced in the risk analysis to test how these two risk variables affect travel demand.
- The risk variables are then chosen to represent one or more risk factors identified in Step 1.

Step 3. Narrow risk variables to key variables for inclusion within each forecast year of analysis

- Sensitivity runs of the FL Statewide Model are performed for each risk variable that allows for a quantitative comparison of the impacts of each risk variable on travel demand.
- Based on the range and known sensitivity of the risk variables under consideration, a final set of risk variables are selected for inclusion for each forecast year.

Steps 4 and 5. Develop a range and distribution for each risk variable under consideration

- The uncertainty associated with each risk variable is quantified by assigning a range and distribution for each variable. For example, based on research on each risk factor affecting auto operating cost, such as fuel cost and fuel efficiency, the range of future auto operating cost per mile in the future is predicted.
- For each risk variable, the minimum, most likely, and maximum values for each forecast year are developed based on currently available research and analysis.
- The shape of the distribution for each variable determines the likelihood of the variable's value, within the set range, under random sampling. For example, it is very unlikely that auto operating cost will be the minimum value of \$0.15 per mile or the maximum value of \$0.31 per mile, but very likely it will be close to \$0.20 per mile. The auto operating cost distribution is defined such that the most likely value will be chosen at a much higher rate than the extreme values, and thus the simulated model runs will be more representative of potential future outcomes.

Steps 6 and 7. Run the Florida Statewide Model using a defined set of risk variable levels to obtain data points for estimation of regression models (i.e., meta-models) that regresses the risk variables on travel demand

- The set of Florida Statewide specified model runs are developed to:
 - Test for the presence of two variable interaction effects;
 - Estimate nonlinearity of model variables;
 - Adequately capture the boundaries of the solution space; and
 - Ensure that data points do a good job of representing the interior of the solution space.

Step 8. Perform a Monte Carlo simulation by running the regression model multiple (10,000 to 50,000) times with varying levels of the input variables based on the distributions assigned to the variables

- The simulation results in probability distributions of travel demand.
- The results of the simulation are then analyzed to determine the relative contribution of each risk factor on travel demand.

5.2 Risk Analysis Process

In order to quantify forecast uncertainty, many model runs are needed, preferably thousands which is a time-consuming process. Since running the model thousands of times is infeasible, it is necessary to develop a simpler meta-model to represent the performance measure of the model that is of interest. Developing a meta-model for uncertainty quantification is somewhat new to the field of travel demand forecasting, but relatively common in other fields. One key to meta-model development is running a limited number of model runs from which to estimate the parameters of the meta-model. Selection of those full runs is critical. One method (done in California for the High-Speed Rail study) is to combine elements from two experimental design approaches to specify an efficient number of full runs to estimate the meta-model parameters - Fractional Factorial designs and Probabilistic designs. A two-step analysis process employing two sets of experimental designs is done to identify the efficient number of full model runs:

- The first set enable the testing for interaction effects of the independent risk variables.
- The second set, based on the findings from the first set of runs, allows to keep the number of model runs to a reasonable number but provides the information necessary to test for non-linearity of risk variables and ensure that the full model runs represent the solution space adequately.

Classical experimental design, such as Fractional Factorial design, is useful for evaluating which variables are contributing substantially to differences in responses, allowing for estimation of interaction effects, and capturing the edges of the solution space. Sampling and Space Filling Designs (like uniform or Monte-Carlo random sampling) sample from points throughout a design space and are useful for ensuring that the solution space is well represented and allows for the testing of non-linearity of the regression variables. To quantify uncertainty, it is useful to include both approaches since the Fractional Factorial design helps understand extreme values and tails of distributions while the sampling helps fill in the space in the middle of the distribution where most results lie.

The first step of the analysis includes running model runs using only a fractional factorial design to determine the existence of two-factor interaction effects. Based on the findings of step one, the final experimental design for Step 2 is modified to include a reduced number of full model runs for each alternative and forecast year to develop the meta-model linear regression equations as a function of the ten risk variables.

6.0 Checklist for Model Application

The FLSWM is a useful resource for travel demand forecasting in Florida, but it is not always going to be the right platform for every project. Before turning to the FLSWM, a project planner should consider three basic questions:

- Can the FLSWM provide the forecasts needed?
- Do I have the input data necessary to use the FLSWM?
- Is there a better tool to use?

This section will help users consider the answers to these questions.

6.1 Can the FLSWM provide the forecasts needed?

For any modelling application, it is important to understand the capabilities and limitations of the underlying model, as these will limit the scope of useful model applications in important ways. For the FLSWM, the most important limitation of the model is through the nature of the outputs: the model generates measures of volume and congested speeds on highway links. As discussed above, a number of other measures (economic impact, air quality, toll revenue, etc.) can be derived from these principal outputs. Other measures not derived directly from volume or speed are not available from the FLSWM. For example, measures of road safety, while loosely coupled with speed and volume, are also heavily dependent on other factors (road design, traffic enforcement, etc.) and the outputs from the FLSWM need to be fused with other factors in order to derive safety performance measures.

The focus of the FLSWM is on the **state's highway system**. Although the freight components of the model incorporate freight movements by rail, water, and air in addition to trucks, these other transportation modes are not modeled in great detail (notably, capacity constraints and congestion effects are omitted), and passenger travel by other modes is not explicitly modeled. This means that the FLSWM can typically be a good choice for forecasting the performance of the highway network and for evaluating the impacts of highway-centric infrastructure projects, but it will often be a poor choice for forecasting the performance of other transportation modes.

This is not to say that the FLSWM is always inappropriate for evaluating the impact of investment or other changes on aspects of the transportation network outside the highway system. For example, the FLSWM can be used to evaluate the creation of a new truck-to-rail intermodal facility, both through a detailed measurement of impacts on the highway network (examining changes to congestion and travel times link by link) and less detailed but still possibly relevant freight flows on the rail network (gross tonnage by commodity traveling on particular routes). Changes to passenger flows at airports and seaports can also be captured as model inputs, through adjustments to the "special generator" trip attraction rates. However, these changes are necessarily *inputs* to the model, and are not an *output* from the model; the framework used for the passenger components of the FLSWM prevents the model from generating forecasts for passenger travel by any mode other than automobile. Greater scrutiny should be given to possible applications of the FLSWM for the evaluation of transportation enhancements or policy changes that impact non-highway travel, to ensure that the model is being applied appropriately.

The current version of the FLSWM model does not include a time of day or peak/off-peak modeling component, so it will not be possible to differentiate trips into related temporal categories; all trips are modeled based on daily trip rates. Consequently, congestion and delay are modeled as daily averages, and are not differentiated into times of day. Differentiation of trips by time of day can possibly be approximated by post-processing the output data from the FLSWM, although this would require a separate time of day model, and substantial additional effort for processing and validation.

Moreover, due to the mathematical construction of the model, the trip generation components of the FLSWM model are not sensitive to attributes of the transportation system. (This is common for traditional “four-step” and related models.) While this limitation is perfectly reasonable based on the available data and modeling technologies, it prevents the model as constructed from internalizing possible “induced demand” (i.e., a new highway encourages existing households near its route to make more trips than before, instead of merely re-routing the same trips to different places).

6.2 Required Data Inputs

Successful application of the FLSWM as the full statewide level requires an extensive set of data inputs, although the data required for application is not quite as comprehensive as that required in the estimation and calibration of the model, as many model parameters are pre-determined. The following inputs are required to generate forecasts:

- Highway Network

The attributes of many links in the highway network do not change from year to year, but it is still necessary to ensure that the network is adequately updated for each forecast year. This includes the addition of links to represent new facilities, and updating existing links to reflect changes in built attributes (e.g. number of lanes, speed limit, etc.). The FLSWM model as published includes links for all existing major roads, as well as major roads that are already planned for construction before 2040. The data format for the network file allows for differentiating the relevant built attributes by year, so that it is not necessary to create separate network files for different years.

- Socio-Economic Data

The FLSWM requires a forecast of population attributes in each TAZ within Florida. The data required for each TAZ for each forecast year is described in Appendix A. The FLSWM provides a central (most likely) forecast for this data in 2040.

- Employment

Both the freight and passenger models utilize employment totals by zone, for firm generation and trip attractions rates, respectively. The base year freight models are built with observed business establishment data, but no equivalent dataset exists for future years, so the freight model relies on employment data instead. The released FLSWM includes a central forecast for employment in 2040 by employment category.

- Commodity Flows

The base year freight model uses observed commodity flows from FAF3, which is not available for forecast years. Instead, current year flows are adjusted by IHS central growth forecasts to define flows for 2040.

The FLSWM as currently released is prepared to directly support scenarios in the base year (2010) and one forecast year (2040). All of the necessary input data is already included for “baseline” forecasts in those year, assuming already planned projects in the pipeline will all be completed by 2040. Forecast years between 2010 and 2040 are also mostly supported through linear interpolation, although such interpolation is only valid for inputs with continuous growth over time (i.e., population, employment, economic activity). The highway network is a notable exception: new roads or lanes do not sprout continuously but instead are opened for public use at some particular future date. For an interim forecast year between 2010 and 2040, some new facilities will be completed and some will not, and it is necessary to identify those facilities explicitly in order to create an interim year forecast using the FLSWM. Forecasts to years beyond 2040 are not formally supported, although they may be possible through extrapolation. If such forecasts are attempted, their reliability should be considered as relatively low, and further decreasing rapidly with increasing time.

Applying the FLSWM for **scenario planning** involving alternative transportation infrastructure plans will also require modification of the highway or other transportation networks to incorporate the envisioned changes. Scenarios can also be developed for alternative forecasts for population and employment, or localized demand into or out of special generators, which would require specific forecasts for each varied input. These forecasts are not provided with the FLSWM and would need to be generated externally.

If the FLSWM is applied for a subarea or corridor study where only a portion of the state is modeled, additional data may be required. As discussed above, such studies may necessitate the enhancement of the zone system or transportation network with additional detail. In that case, all of the concomitant data will also need to be revised to support the new resolution: the socio-economic and employment data must be disaggregated and attached to the zone system, and relevant roadway attributes will need to be attached to all links added to the network.

6.3 Is there a better tool to use?

Even if the FLSWM appears to be an effective tool for any particular application, it may not always be the best approach. For example, in instances where the study area is contained entirely within the modeling area of a single MPO or regional model, it will generally be simpler to use that tool than to adapt the FLSWM for use. MPO models generally will have better detail, will already be more carefully calibrated and validated for the particular area, and will be more likely to be sensitive to relevant local factors (e.g., where transit is important it will be included).

The FLSWM will also generally be most suitable for reasonably large-scale projects that have regional implications. Even in areas outside any MPO or regional model, applying the FLSWM would not be particularly effective or useful to evaluate **small scale changes** in traffic flow. For example, the opening of a new Publix or other supermarket in a small town outside any MPO might trigger significant traffic impacts in a highly localized area around the new store, but negligible impacts elsewhere. Such a project would best be evaluated by a smaller scale traffic study, which could take account of relevant operational details (e.g. signal timing, street geometry) while safely ignoring traffic impacts on the rest of the state.

In some instances, the outputs from the FLSWM by itself might be inadequate to answer policy questions raised by decision makers. However, when used in conjunction with post processor tools, which take the

model inputs and outputs along with other data and factors, the FLSWM becomes a powerful analytical tool for policy making. An example of the use of a post processor tool is the air quality post processor that accepts emissions factors from MOVES as a look-up table, and applies this input to link-level VMT in the FLSWM to calculate emissions for each pollutant.

Freight plays a vital role in the national, state, and local economy. But its specific contribution is difficult to quantify, and the mechanism of impact of freight transportation investments on economic production is not clear. Traditional cost-benefit analysis focuses on the cost and benefits of building specific facilities at the project level. This is insufficient and underestimates the true benefits of freight as it does not take into account the multiplier effects that freight brings to the economy as a whole. To overcome this, the Florida Freight Transportation Economic Impact Kit (FTEIK) was developed based on regional economic input-output model and the freight component of the FLSWM – Freight Supply-chain Intermodal Model (FreightSIM). The core of FTEIK lies in the combination of a freight demand model with a multi-sectoral economic model. Outputs from FreightSIM are converted into money values which are the inputs for the regional IO model to derive sectoral impacts for the studied economy. The kit also allows users to customize values for converting transportation outputs at the project level. The output from FreightSIM is vehicle miles traveled (VMT) and vehicle hours traveled (VHT). It is assumed that freight transportation investment (e.g. new highway investment) would in the long run lead to more efficient freight traffic with less vehicle hours of travel on the highway links in the study area.

6.4 Circling Back

The checklist provided here is not just a one-off guide for the suitability of using the FLSWM for any particular application, but the concepts it embodies should remain at the forefront of any analytical efforts undertaken using the model. Model users should remain vigilant regarding the capabilities and limits of the model during and after model application, to ensure that the results of any modeling effort are used appropriately. The FLSWM is a powerful tool for forecasting travel demand for a wide variety of purposes, and proper usage across many applications will ensure it remains a trusted tool for planners and policy makers across Florida.

7.0 Appendix A: Data Used in Modeling

7.1 Zones

The Florida Statewide Model is based on 8,518 travel analysis zones (TAZs) within the state, to represent the various possible origins and destination of trips. This yields an average zone population of about 2,000 persons, although zones are not drawn to with respect population alone, so there is substantial variation in resident population among zones: over 200 zones have populations exceeding 10,000 persons, while over 300 zones have no residential population at all, at least in the base year. Many of these zones with no population do have significant employment, which attracts passenger trips, and they may produce or attract freight trips as well.

For passenger travel, only the travel actually within the state of Florida is modeled. Trips that enter or leave the state are modeled only from the in-state origin to the state line, or from the state line to the in-state destination. To support this approach, 60 external zones are defined at the state line where the included roadways exit Florida.

Freight travel is handled differently, as the final destination for freight trips plays an important role in mode choice, even when the destination is far from Florida. For example, shipping bulk freight from Miami to New York by water might be reasonably cost efficient, but not for shipping the same freight to Dallas, which is about the same distance from Miami but has no port or major waterway access. To support this modeling detail, the freight model has zones that span the world, although with decreasing resolution as the distance from Florida increases. For the nearest out of state destinations, the freight model includes 594 zones in Georgia and Alabama, generally following county boundaries, although some counties nearest to the Florida border are modeled with more than one TAZ. Beyond Florida's immediate neighbors, 183 zones represent the rest of the United States (divided roughly by major metropolitan areas), and 8 zones represents international destinations, including Canada, Mexico, and 6 continent-scale regions, mirroring the zones established by FAF3 in these places¹.

For each zone within Florida, a variety of socio-economic (SE) data is tabulated, both for the base year as well as any forecast years:

- Number of dwelling units (DU) of various types (single family, multifamily, and hotel-motel),
- Occupancy/Vacancy rates for DUs of various types,
- Auto ownership (propensity of households in each DU type to own 0, 1 or 2 cars),
- Employment by major category (industrial, commercial, service), and
- School enrollment.

For the base year (2010) this SE data is derived from a variety of sources, including the Bureau of Economic and Business Research (BEBR) at University of Florida, and the Property Appraiser Parcel Database. This data is cross checked for validity against information from the U.S. Census and the Bureau of Economic

¹ Additional detail on the zone system used in the freight model can be found in Section 3.1: Zone Systems of the FreightSIM Model Users Guide.

Analysis (BEA). For forecast years, a similar dataset must be created for the same variables in the forecast year. The source of the data for forecast years can vary depending on the scenario being evaluated.

7.2 Networks

To model the travel of passengers and freight, the Florida Statewide Model must be built upon a representation of the transportation network within and around the state. While the actual Florida transportation system contains myriad modal choices for both passengers and freight (automobiles, trains, buses, etc.), for passenger travel the statewide model focuses exclusively on cars using highways and major roads. By limiting this model to just automobile travel, the complexity of the model is greatly reduced compared against a model that would more fully encapsulate multi-modal transportation. This limitation is particularly reasonable given the scope of applications of the statewide model: almost all usage of transit services in Florida occurs *within* metropolitan areas and regions that have more detailed local transportation forecasting models. Since this model is designed for applications outside or between such areas, accounting for such travel becomes substantially less important.

In addition to being limited to only roadways, the statewide model is restricted to modeling travel only on major roads and highways. No attempt is made to include all roadways in the state, in large part because of the modest granularity of the travel analysis zones. Including all minor roads is unnecessary, because there is insufficient detail in the TAZs to support assigning traffic counts to minor streets. This simplification aids in model application, as it is not necessary to externally maintain detailed and up-to-date data on every minor street in the state (saving on data collection, maintenance, and storage), and it also not necessary to perform calculations for traffic assignment and delay on all of these minor streets (saving on computational time).

For those roads that are included in the model, a variety of basic roadway attributes are specified:

- Facility type (Freeway/Expressway, Divided/Principal Arterial, Undivided/Minor Arterial Volume, Collector, One-Way, Ramp, HOV, or Toll Road),
- Area type,
- Number of lanes,
- Free flow speed (i.e., the posted speed limit), and
- Roadway capacity.

As for the SE data discussed above, these attributes must be identified separately for the base year as well as any forecast scenario years, although in many cases the attributes will not change over time. Additionally, roads can be flagged to be added or removed from the network for future scenarios, and for membership in a variety of categories for summary analysis (e.g. by District, County, or Corridor).

In addition to the network data, certain links have or may have a toll collection facility. Information about tolling (the amount of the toll, how it is collected, etc.) is stored in a separate file from the other highway network data, but conceptually is tightly integrated with the network.

A subset of network links also have traffic counts, based on observed data collected on the link. This count data is used in part to calibrate and validate the model.

The network representation also includes zone centroids and centroid connector links. The centroids represent the zones themselves, and each zone has one centroid, which is where modeled trips originate and terminate. Centroid connectors are a special kind of network link, which notionally connects zone centroids with the rest of the highway network. These centroid connectors take the place of smaller feeder streets that are not otherwise represented in the model, but unlike other highway links these connectors do not map to “real” roads and do not have real travel times or roadway attributes associated with them.

7.3 Passenger Trip Generation

The trip generation components of the model develop a forecast for how many trips will be produced in, and attracted to, each TAZ within Florida. The primary data inputs to this component include the zone system with the related SE data for the population and employment within each zone. This data is used by a trip generation model to create the bulk of passenger trips for the FLSWM.

In certain cases, the standard model for trip generation is unable to closely match the number of trips generated or attracted based only on the population or employment information in the available SE data. These trips are handled by designating particular facilities as “special generators”, which attract passenger trips at rates greater than would be modeled based purely on population and employment factors. For the FLSWM, these special generators include airports, seaports, and Disney theme parks. Trip generation rates for each special generator are created through a separate individualized study of the traffic associated with the particular facility.

In addition to these trips that are both generated and attracted within the state of Florida, the model must generate trips that are either produced or attracted in areas outside the state. This trip productions and attractions are not generated from SE data, but instead are based on observed and historical traffic counts at the state line.

Because of Florida’s geography, it is not expected that there is, or ever will be, any significant external-external travel (i.e., through trips). Thus, these trips are not considered at all in the Florida Statewide model.

7.4 Passenger Trip Distribution

The trip distribution components of the model provide the linkage between the productions and attractions, i.e. where do particular trips start and end? Since no statewide origin-destination survey was available for the calibration of this model component, it is calibrated based on the Turnpike Statewide Model.

7.5 Passenger Auto Occupancy

The auto occupancy component is used to convert from person trips to vehicle trips. It is based on FHWA TMIP guidelines. This model component is not otherwise calibrated, and relies on no other outside data.

7.6 Freight Generation and Distribution

The freight model relies on a variety of data sources: the zone system, the highway network, multimodal transfer and access points for non-highway modes, and economic activity data including commodity production and consumption, freight flows, and employment. The first several components of the freight model are not sensitive to the transportation system, as they rely only on economic data and great circle

distance between zones. These components include Firm Synthesis, Supplier Firm Selection, Goods Demand, and Distribution Channels.

The Firm Synthesis component of the freight model generates a synthetic dataset of all firms in the United States and a sample of international firms, and allocates firms to traffic analysis zones (TAZs) outside of Florida. Within Florida, the employment data at the TAZ level is used instead. This model component uses the zone system described above, along with County Business Pattern (CBP) Data from the U.S. Census to generate firms outside Florida, and more detailed *Infogroup* business data to generate firms within Florida. Firms are initially generated by County (in Florida, Georgia, and Alabama) and by FAF zone elsewhere, and then disaggregated to the TAZ level where necessary in Florida, Georgia, and Alabama. The result of this component is a list of firms by industry and employment in each TAZ.

The Supplier Firm Selection, Goods Demand, Distribution Channels, and Shipment Size and Frequency components of the freight model link producing firms with consuming firms, and determine the type and overall tonnage of freight that is transferred, and establish a basic supply chain framework. These components are based on data from a variety of sources, including:

- Input-Output Make and Use Tables from the U.S. Bureau of Economic Analysis
- Industry to Commodity Correspondence from Freight Activity Microsimulation Estimator (FAME)
- NAICS6 Industry to Input-Output Industry Correspondence from the U.S. Bureau of Economic Analysis

7.7 Freight Modes and Transfers

The modes and transfers component of the freight model predicts the usage of four primary modes (road, rail, air, and waterway) and transfer locations for shipments with multi-stop supply chains.

In addition to the usual highway network outlined above, the freight modes and transfers model relies on a representation of the rail, air, and waterway networks, and a set of transfer nodes that links the various modal networks together and allows for intermodal transfers. Congestion is not modeled on the air, rail, and waterway networks, and costs are estimated based purely as a function of network distance, so the detail required for these networks is substantially less than that required for the highway network. Network connections for these modes need not account for capacity or geometry, but instead merely represent the distance and connectivity of the network. Within the Florida Statewide Model, these networks are not even graphically represented, as they are simply expressed in terms of the network skims, which give the network distance between nodes. The underlying data for the rail, waterway, and air networks is provided by ORNL, the US Army Corps of Engineers', and the Bureau of Transportation Statistics, respectively.

7.8 Highway Assignment

Assignment identifies the routes taken for each trip, both for passenger and freight trips. These two types of trips are assigned simultaneously because they share the highway network, and roadway congestion is caused by both together. The input data is the highway network (described above) and the trip tables (created by the previous model steps).