Final Report: Validation and Sensitivity Considerations for Statewide Models

NCHRP Project 836-B Task 91

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)
Standing Committee on Planning

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DISCLAIMER

final report

Validation and Sensitivity Considerations for Statewide Models

NCHRP Project 836-B Task 91

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prepared by

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1.0 Introduction

Historically travel demand models have been primarily created for urban and regional areas and have focused on forecasting travel demand within metropolitan areas. In the last 15 to 20 years, many state Departments of Transportation (DOT) have undertaken the development of statewide transportation demand models. Statewide models are used to forecast travel demand for the entire state and often areas within contiguous states. Urban transportation models focus on travel within and through the urban area. These trips, for the most part, are short-distance home-based and nonhome-based trip purposes. Conversely, statewide models focus on long-distance trips, freight, intercity, and rural trips that are frequently categorized into business, personal, and recreational purposes.

To date, over 30 states have developed or are developing statewide models. These models are often used to help formulate policies, to prioritize projects, and to identify the potential revenue streams from toll road, intercity rail, and other major transportation investments. Because these models play such a significant role in the planning process, careful and thoughtful evaluation of how well these models reproduce existing travel markets as well as their sensitivity to major market segments and behavioral responses is an increasingly important consideration for state and Federal DOTs. Most of these statewide or superregional models are built upon practices originally developed for a monocentric urbanized area.

NCHRP SYNTHESIS 358 Statewide Travel Forecasting Models[1] provides the first comprehensive examination and inventory of statewide models in the U.S. This effort did not, however, include validation and sensitivity considerations for this relatively new class of model. NCHRP Synthesis 358 highlights the ways in which many of these statewide models are different from their urban counterparts. For urban and regional models, there are many sources of guidance on validation and reasonableness checking such as *NCHRP Report 365* and the *FHWA Model Validation and Reasonableness Checking Manual*. These documents provide a set of excellent resources to evaluate urban models but do not provide any guidance on how nonurban (regional, superregional, and statewide) models should handle validation considerations, performance standards, and/or sensitivities.

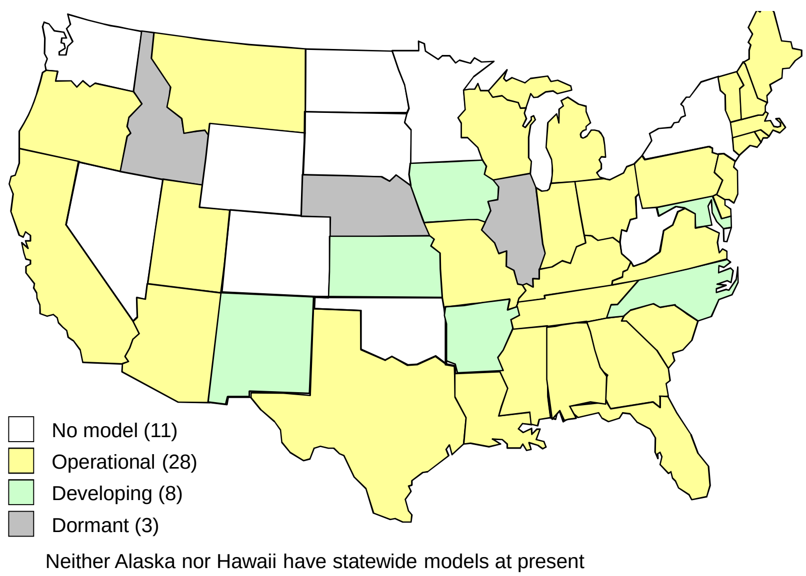
This report documents validation and sensitivity issues that should be considered in the development and deployment of statewide models. This report

[1] Horowitz, Alan J., University of Wisconsin-Milwaukee. *NCHRP Synthesis 358 – Statewide Travel Forecasting Models.* Prepared for Transportation Research Board of the National Academies, April 2006.

should act as a supplement to the FHWA and NCHRP guidance on model estimation and validation for urban models and highlight ways in which statewide models should be treated differently from urban models. As preparation for this report 30 statewide models were reviewed as well as numerous documents on travel demand modeling. A full list of reviewed documents can be found in Appendix A, Bibliography.

Figure 1.1 depicts the current status of all known statewide models in the U.S. Operational models are current models that are used and maintained for travel demand forecasting. Developing models are under development at the time of publication. Dormant models are models that were once operational but are no longer in use whether due to maintenance errors or their original purpose is no longer valid.

Figure 1.1 Current Status of Statewide Models



Source: A. Horowitz, *Statewide Travel Forecasting Models, NCHRP Synthesis 358* (2006), with recent updates.

This report describes statewide models in the context of rationale, common practices, reasonableness, sensitivity, validation, modal issues, freight integration, and integrated transportation and land use models. A goal of this document is to provide guidance for statewide model developers and users to enhance statewide model validity and sensitivity. Since the characteristics of states vary drastically, it is impossible to create one standard to be applied to all states. It is important that states consider their goals and objectives for a statewide model, and let those guide the type of model that is developed and the standards that should be applied to it. The next subsection provides background on the rationale for statewide models in order to put validation and sensitivity into their proper context.

1.1 RATIONALE FOR STATEWIDE MODELS

Transportation modeling has for the most part focused on urbanized areas, but statewide models are becoming more common. Each state faces planning challenges that are unique to individual situations. Therefore, when creating a statewide model, states must identify what issues are most important. Identifying key issues will allow states to develop a statewide model structure that will work best to meet stated goals. This section of the report looks at the rationale behind how and why states develop statewide models.

Metropolitan planning organizations (MPO) have models that forecast travel demand for urbanized areas, but these models do not forecast demand on intercity corridors and rural highways. To develop a better understanding of travel demand, many states have turned to creating statewide models. Since models already exist for urbanized areas, states have decided, by and large, to integrate urban models within the statewide models. Whether the states choose to include intra-urban trips or not, all states seem to agree that key purposes of statewide models are providing support to MPO models (e.g., external trips), conducting strategic transportation policy and corridor planning analysis, and evaluating intercity investment decisions.

In addition to supporting analysis and decision-making, there are many other factors that go into the development of statewide models. Many models were developed as part of a statewide long-range plan. Listed below are examples of reasons identified by states for developing a statewide model based on a review of study documentation.

- **Arizona** used the statewide model as an analysis tool to identify the regional transportation needs of future population centers in an effort to get ahead of the State's rapid growth.
- **Delaware** and **Florida** both have major toll corridors running through their states; therefore, each decided to include toll models to identify demand for future toll corridors.
- **Iowa**'s initial statewide travel forecasting efforts focused on the movement of grain as a freight commodity.
- **Kentucky**, **Massachusetts**, and **Rhode Island**'s statewide models were created in part to analyze the effects of transportation on air quality.
- **Oregon** wanted an integrated statewide model that combined land use, economic activity, and transportation demand.
- In **New Jersey** the need arose to have one model to identify project impacts at a statewide level; therefore, five regional models were combined to create the New Jersey Statewide Model.
- In an effort to make use of available data sources, the **New Mexico** model was created by combining available GIS statewide network and socioeco-

nomic data that could be integrated with other modeling tools such as micro-simulation, benefit/cost, freight, and toll diversion tools.

- **Virginia** and **Tennessee** are examples of statewide models that were created for developing statewide plans, but include extra capabilities for use in other projects (e.g., Tennessee model was subsequently used for a statewide I-40 Corridor Feasibility Study[2]).
- Because **Wisconsin** experiences relatively high amounts of intercity travel, the State chose to focus on intercity auto and intercity transit demand.

The examples listed above show that there are many policy-oriented and technical reasons for creating a statewide model and each is unique to a state's ultimate goals. However, all states with statewide models use them as tools to help analyze alternatives and support investment decisions. The models provide projections and visual aids that help analysts, planners, decision-makers, and members of the public to better understand the impacts of different proposed project alternatives and land use policies. Many statewide models are used to develop statewide long-range plans required by Federal law. The Department of Transportation Appropriations Act, the predecessor to ISTEA, TEA-21, and SAFETEA-LU, provided funding to states for data development and analysis, including the development of statewide models.

While developing a statewide model, there are many considerations. The type of projects a state wishes to study in part determines the level of detail required of a statewide model. Indiana and Florida have used tier systems, evaluating model forecasts at statewide, district, and corridor levels. Some states, such as New Mexico, start off with more basic goals, forecasting passenger and freight trips; while others have more specific goals in mind, such as California's Statewide High-Speed Rail (HSR) Model. The California HSR model was developed for the Bay Area Metropolitan Transportation Commission and the California High-Speed Rail Authority. Another statewide model, maintained by Caltrans, is focused on intrastate vehicular travel. It too is a multimodal model, but not too much is done with the nonhighway modes other than making sure that the vehicle flows are reasonable. Most states have analyzed average weekday traffic; however, Massachusetts has focused on time-of-day modeling, for the purposes of highway design and the related need to forecast design-hour conditions.

These are examples of some of the considerations states must make when developing a statewide model, showing that each state and its needs are unique and based on their ultimate goals. How statewide models are applied also is important to model validity and sensitivity, hence the following discussion on common model applications.

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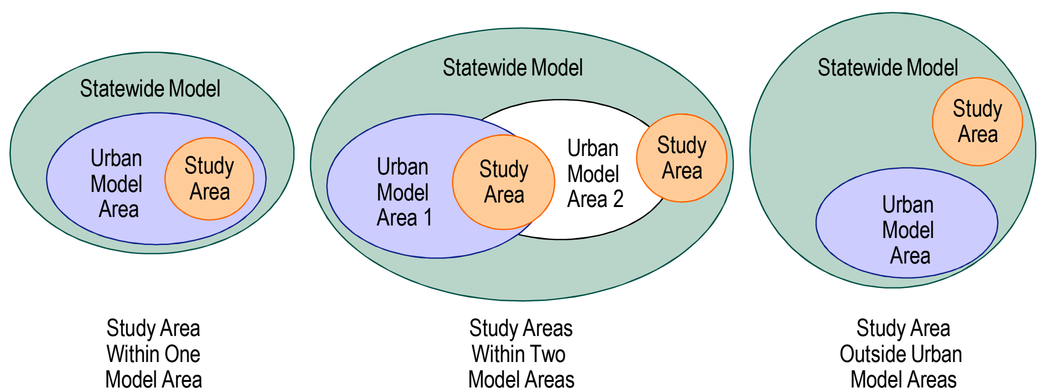
[2] Robert G. Schiffer, Cambridge Systematics. *Integrating Statewide and MPO Models: I-40/I-81 Feasibility Study*. Presented at TRB Conference on Best Practices for Statewide Planning, Atlanta, Georgia. September 2008.

1.2 Common Applications for Statewide Models

Urban models have traditionally focused primarily on routine short-distance trip purposes and are used to analyze corridor-level projects that affect roads or transit facilities within the modeled network. Statewide models emphasize long-distance and interregional travel. In addition, states have discovered multiple applications for statewide models, some similar and some different from the applications of urban models. Some of the most commonly identified applications of a statewide model are interregional corridor studies and other project analyses that have a regional impact beyond the boundaries of an urban model. As depicted in Figure 1.2, this includes study areas near urban model boundaries, study areas that straddle multiple urban area models, and study areas that are outside urban model boundaries entirely. Additional uses include rural area air quality analysis, toll studies, external travel forecasts, population center forecasts, multimodal analysis, recreational travel, and freight forecasts. This section details the statewide model applications identified in the reviewed reports.

Figure 1.2 Context for Application of Statewide Models



Source: Florida Department of Transportation and Cambridge Systematics, Inc.

Since most statewide models focus on intercity and rural trips, states use the models to perform interregional corridor studies. These corridor studies are generally for projects and alternatives that have a regional impact, rather than a contiguous impact on local roads within an urban model. States also rely on statewide models to analyze general transportation needs for an entire region or group of regions. Multiregional analysis can be used to identify corridors or segments that will need additional capacity to keep up with growth patterns throughout the state. Often the analyses are used to generate statewide long-range transportation plans that identify the infrastructure improvements needed and the state's plan of action.

Freight plans have become critical in statewide transportation planning, and most states have either developed or are in the process of developing statewide freight models. The nature of goods movement makes statewide models ideally suited to simulating such travel. These models are usually integrated with statewide passenger models. Freight models can be used to perform benefit/cost analysis of plans, forecast demand on existing or proposed freight corridors, and forecast the impacts of growing freight centers. Of the 30 statewide models reviewed, 14 had some form of freight or truck model, and other states including Alabama and Rhode Island are in the process of developing freight models. Since 1995, freight traffic has grown at a faster rate than all other classes of highway traffic, and is expected to double between 2000 and 2035.[3] Because of the high-growth rate of freight trips, more states may decide that freight model applications are needed in addition to the statewide passenger models.

Analysis of transportation-related air quality and greenhouse gas emission impacts has grown in interest in recent years. Kentucky, Massachusetts, Wisconsin, and Rhode Island each reported using statewide models to estimate quantities of air emissions from mobile sources. Air quality is regulated by the Clean Air Act. The Federal government continues to focus on passing new environmental legislation. Due to potential new legislation and interest in climate change analysis, it is expected that more states will use statewide models to calculate emissions of greenhouse gases.

Florida and Delaware both included toll simulation capabilities in their statewide models. The models are used to forecast travel on toll roads and predict the feasibility of additional toll facilities. Due to limited transportation funding, many states have looked at toll facilities to help fund transportation projects. Florida has an extensive toll network throughout the State and, because of its large number of toll facilities, has created the Florida Turnpike State Model to evaluate intercity toll demand. In Delaware, there are two limited access toll roads (I-95 and SR 1) that are heavily utilized. These toll facilities help fund the State's transportation improvement projects, and the State has applied a toll modeling methodology in the statewide model to forecast the future demand, determine the need for new facilities and possible locations.

In addition to urban models being a count and network data source for statewide models, statewide models can provide data to urban models. Urban models rely on local travel surveys to validate intraregional trips, but it is unlikely the surveys include a statistically valid, unbiased sample of external or long-distance trips. Since external trip data are not always available, and statewide models focus on forecasting long-distance trip types, urban models can use the forecasted data from statewide models to validate trip types that are not commonly included in regional travel surveys. Statewide models also can evaluate the impacts of trips passing through a given state.

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[3] Michael S. Bronzini, George Mason University. *Relationships Between Land Use and Freight and Commercial Truck Traffic in Metropolitan Areas*. Prepared for the TRB and the Division on Engineering and Physical Sciences, 2008.

1.3 Report Organization

The purpose of this report is to document validation and sensitivity issues that should be considered in the development and deployment of statewide models. The report will act as a supplement to Federal guidance on model validation for urban models and highlight ways in which statewide models should be treated differently from urban models. For the study, 30 statewide models were reviewed based on common issues and topics related to statewide model development, validation, and sensitivities. Section 2.0 describes the market segments used in statewide models, including exogenous factors, trip purposes, modes, freight, travel periods, and common data sources. Section 3.0 discusses reasonableness comparisons and statistical targets that have been applied to statewide models, along with validation and sensitivity criteria. Similarities and differences with urban models are also identified. This section also includes an analysis of the relationships between urban, regional, and statewide models, along with information about validation and the sensitivity of statewide models. Section 4.0 examines modal issues common in statewide models, including modes forecasted, modeling approaches, and validation of mode choice models. Statewide freight models are discussed in Section 5.0. Recently, states have begun to integrate transportation and land use models; this topic is discussed in Section 6.0. Lastly, a summary of the report, along with conclusions, is provided in Section 7.0.

2.0 Market Segments Found in Statewide Models

Statewide models are generally structured to focus on different market segments than those found in urban and regional transportation models. For example, differences among typical urban trip purposes are not nearly as important as the predominant types of long-distance travel typically emphasized in statewide travel demand forecasting models. However, in smaller states, primarily in the Northeast U.S., it is common for statewide models to be similar to urban and regional planning models in terms of trip purposes, transportation modes, and network/zone structure.

All 30 statewide models reviewed during this study sought to measure intercity and rural travel demand, but many different stratifications were used. Information has been compiled during this study on market segments, trip purposes, transportation modes, freight approaches, and travel periods used in statewide models. This section of the report discusses each of these topics in relation to the existing statewide models reviewed.

2.1 Segmenting Trips in Statewide Models

Market segmentation within statewide models is determined in part by the complexity of the model, which is a function of anticipated uses of the model and issues to be addressed. This is especially true at the two ends of the spectrum in model sophistication. At the low end of complexity are synthetic origin-destination matrix estimation models while at the high end are activity-based models. Geography and urban development patterns also can impact the market segmentation of statewide models, sometimes requiring the modeling of areas outside the state.

Synthetic models developed for the states of Georgia, New Mexico, and Tennessee use origin-destination matrix estimation (ODME) procedures to adjust a seed matrix into a trip table factored and validated to simulate available traffic counts. ODME replaces the trip generation and distribution process and sometimes mode choice as well, hence negating the benefits of multiple trip purposes and market segments such as different trip lengths and mode splits. While the Florida DOT has a four-step statewide model, its Florida Turnpike Enterprise Office has prepared a separate statewide ODME model, reflecting their focus on vehicle trips and market segmentation by toll user types rather than trip purpose, etc. In geographically small states it is common for statewide models to include portions of adjacent states such that routine commute patterns are contained within the model. For example, the Delaware model[4] includes Maryland's eastern shore to account for trips taken throughout the entire "Delmarva" peninsula. Many statewide models include bordering counties or zones in adjacent states, creating a "halo" of zones to capture external trips. This "halo" of zones also is common in states with metropolitan areas that straddle a state line. Model structures and available data in adjacent states can become a factor in determining the trip purposes and market segments used in a statewide model. In applications that need to be sensitive to complex cross-state commute patterns and sociodemographic factors (e.g., income tax in only one state), some states have found it useful to incorporate the principles of activity-based modeling (ABM), tour-based modeling, and simulation of nonmotorized travel, as has been done in the tour-based New Hampshire Statewide Model.

The use of ABM in statewide models is largely influenced by the types of issues to be addressed by the models. Deployment of ABM in urban and regional models in a state may make it easier to support a statewide ABM model. For example, Ohio and Oregon both have statewide activity-based models that, in part, reflect the presence of ABM in the Columbus and Portland regions as well as the desire to address issues that are not ideally suited to four-step modeling such as land use interaction, economic factors, and peak spreading.

Integrated transportation and land use models have become more popular among statewide models. These models include many factors, including location of activities, economics, land use, and transportation. Integrated transportation and land use models are detailed in Section 6.0 of this report.

2.2 Trip Purposes

Nearly every four-step statewide model has classified trips into home-based work (HBW), home-based other (HBO, or home-based nonwork, HBNW) and nonhome-based (NHB) trip purposes. Further disaggregation into additional home-based and nonhome-based purposes is not as common, with only a few statewide models including additional purposes. In most statewide models, HBW, HBO/HBNW, and NHB are considered the short-distance trip component. Other trip purposes include various long-distance, truck, and external trips. Table 2.1 presents a comparative summary of trip purposes used in statewide models.

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[4] WR&A and Delaware Department of Transportation. *An Integrated Approach to Statewide Travel Modeling Applications in Delaware.* Presented at the TRB Annual Meeting, January 2009.

Table 2.1 Trip Purposes by Statewide Model

Trip Purpose	Statewide Model (Where Trip Purpose Information Was Available)																				
	AL	AZ	CA	CT	DE[a]	FL 2000	IN	KY	LA	MA	MS	NH	NJ[b]	OH	OR	RI	TN	TX	UT	VA	VT
Home-Based Work	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●
Home-Based Other/Nonwork	●	●			●	●	●		●	●	●	●	●		●	●	●	●	●	●	●
Home-Based Shop/Regional Shop					●	●				●		●	●	●							●
Home-Based Regional Shop					●																
Home-Based Social/Recreation					●	●				●		●		●							
Home-Based School										●		●	●	●							●
Chauffeuring												●									
Nonhome-Based	●	●		●		●	●		●		●					●	●	●	●	●	●
Nonhome-Based Work				●	●					●			●		●						
Nonhome-Based Other					●					●			●		●						
Short-Distance Business			●																		
Short-Distance Commute			●																		
Short-Distance Recreation			●																		
Other Person[c]								●													
Commute Low, Medium, High															●						
Other			●											●				●			
Long-Distance		●					●														
Long-Distance Business			●			●			●		●									●	
Long-Distance Commute			●																		
Long-Distance Personal Business											●									●	
Long-Distance Recreation			●																		

	Statewide Model (Where Trip Purpose Information Was Available)																				
Trip Purpose	**AL**	**AZ**	**CA**	**CT**	**DE[a]**	**FL 2000**	**IN**	**KY**	**LA**	**MA**	**MS**	**NH**	**NJ[b]**	**OH**	**OR**	**RI**	**TN**	**TX**	**UT**	**VA**	**VT**
Long-Distance Tourist								●	●		●									●	
Long-Distance Work																		●	●		
Long-Distance Nonwork/Other			●						●									●	●		
Truck	●							●	●												●
Light Truck															●						
Heavy Truck													●		●						
Commercial													●								
Container															●						
Single-Unit Truck		●																			
Multi-Unit Truck		●																			
External-External	●																				
Internal-External	●																				
Internal-External Business																			●		
Internal-External Other																			●		
Internal-External Short-Distance						●												●			
Internal-External Long-Distance								●										●			

[a] Based on CADSR Transportation Survey (1995 to 2002).

[b] Also includes 16 recreational trip purposes (HBCasino Access, NHBCasino Visit, Casino Bus, HBEvent, HBBeach Access, HBBeach, HBBoardwalk, HBShop, HBDine, HBO, NHBEvent, NHBBeach, NHBBoardwalk, NHBShop, NHBDine, and NHBO).

[c] Other Person (a combination of NHB and HBO).

[d] The Florida Turnpike, Georgia, and Tennessee Models use origin-destination matrix estimation (ODME) to generate trips and therefore do not include trips by purpose.

Most statewide models include some form of market segmentation into long- and short-distance trips as well as recreational and business trips, even when the model includes home-based and nonhome-based purposes. The smaller states of Connecticut, Delaware, New Hampshire, and Rhode Island are the exceptions, in that they do not generally separate long-distance, tourist, and/or business trips from urban model trip purposes (although Rhode Island does separate urban trips from rural and New Hampshire acknowledges tourist travel). The threshold whereby trips get classified into long- or short-distance ranges from 50 miles (one-way) to 100 miles. The Virginia Statewide Model uses 100 *minutes* as the threshold, which is approximated to 75 miles. The rationale for using 100 minutes was that this represented the maximum trip length surveyed in the National Household Travel Survey (NHTS) in 1995 and 2001.

Variations on long-distance trip purposes used in statewide models include:

- Long-distance (single purpose combining all long-distance travel);
- Long-distance business;
- Long-distance commute;
- Long-distance work;
- Long-distance leisure;
- Long-distance other;
- Long-distance nonwork/other;
- Long-distance personal business;
- Long-distance recreation; and
- Long-distance tourist.

The California High-Speed Rail model segments interregional trips into long- and short-distance categories (100-mile threshold) but assumes the same four purposes occur within each (business, commute, other, and recreation). Statewide models for Louisiana, Mississippi, and Virginia included both macro and micro components, each with different zone and network systems. Macro and micro components of the Mississippi model were later merged and long-distance trips were further disaggregated into "interstate" and "intrastate" components, each with purposes of business, tourist, and other.

2.3 TRANSPORTATION MODES

The modes included in statewide models typically differ from those in urban models. Urban models typically have smaller, more concentrated study areas that experience greater variety in transportation modes, including bus and passenger rail systems. In most cases, statewide models are used to estimate intercity and rural travel and these types of trips are often limited to personal auto and truck modes. In some states, local urban trips are included within the statewide model, increasing the number of modes that are included.

In the case of California, four MPO models are incorporated into the High-Speed Rail model, and each includes multiple modes such as intraregional public transit, and interregional commuter rail. The term "intraregional" applies to trips with origins and destinations within a single MPO region while interregional refers to intercity travel between MPO regions. The Massachusetts Statewide Model uses the Boston MPO model mode shares for the portion of the trips with origins and destinations in the Metro Boston region while the New Hampshire Statewide Model has a binary logit mode split model to predict interstate express bus travel. Wisconsin experiences a large number of recurring long-distance trips that utilize multiple modes, including intercity bus and intercity rail. For states that experience high volumes of intercity transit, it is important to include these modes in model forecasts.

Outside the mega-regions of the Northeast Corridor, Chicago-Milwaukee-Northern Indiana, and the West Coast, most statewide models are focused primarily on highway travel. The reason for this is that private automobiles account for the vast majority of intercity passenger trips outside the previously cited mega-regions and intracity travel is not generally a focus of statewide models. The Southeast has traditionally relied on autos for intercity travel, although with recent Federal legislation passed encouraging states to move forward with High-Speed Rail (HSR) proposals, statewide models in the Sunbelt region might begin incorporating regional transit facilities and services (e.g., commuter rail) into future statewide models. As with the California HSR Model, it could become necessary to have the ability to model major regions with urban-level zone and network systems along with commercial air travel. Section 4.0 of this report (Modal Issues) further discusses the topic of forecasting modes in statewide models.

2.4 Simulating Transportation of Freight

While freight tonnages by commodity group are generated and distributed in most statewide models, only truck trips (and sometimes rail trips) are typically carried through to assignment. Commodity groups are treated much like trip purposes for generation and distribution with tonnages being the freight equivalent to person trips on the passenger side of the model. Most statewide models differentiate between light-, medium-, and heavy-duty trucks during assignment, since classification counts can distinguish among truck types with differing payloads and travel patterns. However, while a statewide highway assignment model might be able to accurately simulate total truck counts, models are generally less reliable at matching specific truck classes at traffic count sites coded into model networks.

While highway and rail networks have been used throughout the history of travel demand forecasting, modeling of air and water transportation is far less commonplace. From a network standpoint, air and waterways are difficult to quantify in terms of speed, capacity, and propensity for trip diversion. Air and waterborne transportation have been modeled successfully for passenger purposes using similar approaches to modeling transit; however, very few statewide models assign freight trips for these modes. Florida and Ohio were the only statewide freight models that reported forecasting freight trips for air and water. (It is possible that other models include these trips but did not document them.) These trips only accounted for about one percent of the overall freight trips and were not assigned to a transportation network. Truck trips to air and water terminals might need to be added, since the terminal is unlikely to be in the origin or destination TAZ of a freight database. Section 5.0 of this report (Freight) further discusses the topic of forecasting freight in statewide models.

2.5 Travel Periods

The majority of statewide models simulate travel that approximates average annual daily traffic (AADT), in part because long-distance travel exceeds the timeframe of a time-of-day model. Until recently, the Florida Statewide Model forecasted peak season average weekday traffic but this model is now validated to ground counts of AADT. Documentation on the New Jersey Statewide Model noted calibration to represent a typical Friday in August; however, a set of factors was developed to adjust this trip table to represent any day of the week or month of the year. Besides the statewide ABMs and tour-based models, the only other statewide models to conduct time-of-day trip assignments were the California HSR and Massachusetts models. The California HSR model simulates business and commute mode shares using peak skims and recreation/other trips using off-peak skims. Table 2.2 depicts the time period factors by trip purpose documented for these two statewide models. Time-of-day factors were not readily available for other models reviewed during this study.

Table 2.2 Percent Trips by Time-of-Day by Purpose

California	Peak from Home	Peak to Home	Off-Peak from Home	Off-Peak to Home
Business	46%	34%	4%	16%
Commute	49%	34%	1%	17%
Recreation	39%	39%	12%	11%
Other	43%	39%	7%	12%
Massachusetts	**A.M. Peak**	**Midday**	**P.M. Peak**	**Night**
HBW	36%	25%	26%	14%
HBO	10%	25%	46%	19%
HBS	46%	8%	41%	5%
NHB	9%	19%	63%	9%

Source: Cambridge Systematics, Inc. (see Bibliography for California and Massachusetts document titles).

3.0 Model Validation and Reasonableness Checking

The 2008 Travel Model Improvement Program (TMIP) peer exchange on travel model validation[5] focused discussion on several factors that also affect statewide model validation, such as the need for validation data other than those used for model estimation. While much has been written on reasonableness ranges for urban and regional models, similar expectations have never been published for statewide models. Likewise, data sources and ranges of statistical values are readily available for urban and regional models but not statewide models.

This section presents an initial set of reasonableness comparisons, data sources, and likely ranges of values for statewide models. The information described in this section reflects an extensive review of operational statewide models in 30 states, along with other statewide model guidance and reference documents as provided in the bibliography. As the vast majority of statewide models are consistent with a four-step approach to modeling, most available statistics are summarized by model step later in this section.

The first subsection provides a summary of data sources used in developing and validating statewide models. Then the focus shifts to documented techniques used in statewide model validation, followed by demographics and descriptions of model size as it relates to the numbers of zones and size of the network. Finally a series of model validation comparisons is provided among statewide models, national guidance documents, and observed data. This section concludes with a brief summary of findings.

3.1 Data Sources

Existing statewide models have used many common data sets and publications to verify that the model results are reasonable. Many of the sources were at the national level, due to a general lack of comparable data available from individual states. However, as the popularity of statewide models has grown, interest has increased in new survey efforts to collect long-distance trip data required for evaluating statewide model outputs. The following data sources were referred to by models reviewed for this report:

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[5] Cambridge Systematics, Inc. *Travel Model Validation Practices Peer Exchange White Paper*. Prepared for Federal Highway Administration, Travel Model Improvement Program, December 2008.

- **American Community Survey (ACS) –** The ACS is a continuous data collection effort conducted by the U.S. Census Bureau. The ACS has replaced the Decennial Census long-form and is sent to approximately three million households annually and provides one- and three-year estimates of the data collected.
- **American Travel Survey (ATS) –** The ATS was conducted by the Bureau of Transportation Statistics (BTS) in 1995 to gain information on long-distance travel in the U.S. Recently, FHWA has initiated the American Long-Distance Personal Travel Data and Modeling Program. This new program looks to update the 1995 American Travel Survey (ATS), perhaps on a more regular basis, and begin the process of developing a national passenger demand model with multimodal modeling capabilities.
- **Bureau of Economic Analysis (BEA) –** The BEA prepares economic statistics at National, state, and regional levels. The data are used extensively on the freight side of statewide models to estimate employment numbers and quantify economic growth and industry changes.
- **Census Journey-to-Work (JTW) Data –** JTW data have been collected by the U.S. Census every 10 years. Work trip statistics on travel modes and average commute times are useful as a validation check. JTW has been replaced by the ACS, a continuous data collection effort that provides sufficient annual sampling to equal the JTW.
- **Census Public Use Microsample (PUMS) –** PUMS data include social, economic, household, and demographic data in one- and three-year estimates ranging from state to individual household levels. The unique snapshot provided by PUMS is popular in model estimation.
- **Census Transportation Planning Package (CTPP) –** The CTPP is prepared using the Decennial Census long-form data gathered by the U.S. Census. Since the Census long-form has been replaced by the ACS, the CTPP has been reworked to conform with the ACS. The CTPP includes residence worker and place of work characteristics, and journey to work flows for levels ranging from state to principal city. Cross tabulations can be used in preparing base-year socioeconomic data and statistical household and work trip summaries.
- **Claritas –** Claritas, a private data vendor, provides repackaging of population, demographic and household data for national to local levels. The data can be used to help pinpoint potential areas of growth or decline and map regions by income, housing units by tenure and many other demographics. States have contracted with Claritas and other private vendors to expedite the process of estimating socioeconomic data for statewide zones.
- **Commodity Flow Survey (CFS) –** The CFS is prepared by the BTS and provides data for national and state levels of commodity flows. The data is reported by commodity, origin-destination, mode, tonnage, value, and

distance. The most recent CFS was conducted in 2007, and has been a commonly cited data source for statewide freight models.

- **Dun & Bradstreet (D&B) Employment Data –** D&B, another private vendor, provides detailed employment data at multiple levels ranging from international to local levels, along with latitude-longitude coordinate location points.
- **Employment Security Data (ES-202) –** ES-202 data are prepared by the Bureau of Labor Statistics (BLS) from data collected by the Quarterly Census of Employment and Wages (QCEW). The QCEW data are prepared using information provided by states on local employment and wage statistics. The BLS aggregates the data into national, state, consolidated metropolitan statistical area (CMSA), metropolitan statistical area (MSA), and county levels. Confidentiality requirements in data reporting can be a hindrance in "validating" employment estimates, hence the use of proprietary sources as an alternative.
- **Freight Analysis Framework (FAF) –** The FAF is a database and analytical tool used to forecast future freight demand on corridors and international gateways. FAF commodity flows are commonly used as a way to confirm and validate distribution patterns estimated by statewide freight models.
- **Highway Performance Monitoring System (HPMS) –** The HPMS is prepared by the FHWA and provides national data on highway performance by roadway conditions, performance, and investment needs. The HPMS is relied upon as a key source for traffic counts used in assignment validation for statewide models.
- **InfoUSA Employment Data –** InfoUSA provides detailed business and household data for the U.S. and Canada. The data are very similar to D&B, and are sometimes used in conjunction with D&B to improve the reliability of employment estimates by TAZ.
- **Household Travel Surveys –** Household travel surveys are generally the most reliable source of travel behavior parameters, but also can be very costly. Such surveys also are typically focused on single regions rather than entire states. The ATS (above) and NHTS (below) are the most commonly cited household travel surveys used in statewide model development, either by using the national sample or state-specific Add-On samples.
- **Metropolitan Planning Organizations –** MPOs often work with state DOTs to provide urban and regional data for statewide models in an effort to avoid duplicate data within the models. The biggest issue here for statewide models is whether or not to automatically adopt and aggregate MPO socioeconomic data, thus becoming "married" to the MPO update process, or for the state to independently estimate zonal estimates and forecasts, with the potential for inconsistency with MPO numbers.
- **NCHRP 365 Manual –** NCHRP Report 365 was prepared for the Transportation Research Board (TRB) in 1998 as a reference manual for urban transportation

models. The report is used as a reference for statewide models because no transferable parameters exist at the statewide model level. Unfortunately, most of the references in Report 365 are focused on urban travel conditions, limiting their potential in rural areas of statewide models. This report is presently being updated to reflect data from the 2008 to 2009 NHTS.

- **National Highway Planning Network (NHPN) –** The NHPN is a national network provided by the FHWA that is made up of all interstates, principal arterials, and rural minor arterials within the U.S. Since a major purpose of statewide models is to measure external travel, the NHPN is used by many statewide models as an external network source.
- **National Household Travel Survey (NHTS) –** The NHTS is conducted by the Census, BTS, and FHWA to gather information on daily passenger travel. The data are collected through travel diaries completed by a sample of the population. The data reports trips by purpose, time, length, mode, and additional demographic data that is collected. The biggest shortcoming of the NHTS with respect to statewide models is the limited amount of data available on long-distance travelers; however, state Add-On samples can target rural households, unlike MPO travel surveys.
- **Origin-Destination Surveys –** Origin-destination surveys gather trip origin and trip destination data conducted at roadside locations such as an intersection, interchange, rest stop, or regional activity center where surveyors gather license plate data or asks travelers where they are coming from and where they are going to. Such surveys have been useful in statewide model validation by providing information on travel patterns exiting MPO areas.
- **Regional Economic Models, Inc. (REMI) –** REMI is a economic modeling firm that provides decision-makers with economic tools and data to aid and improve the public policy process. REMI data have provided a foundation for economic forecasting components of statewide models in a few instances.
- **State DOTs –** State DOTs are typically the lead agency in developing statewide models. In many cases the models are part of greater statewide planning initiatives. State DOTs also may conduct surveys or otherwise serve as a primary source for data used in statewide models, particularly on the network side.
- **TRANSEARCH Data –** TRANSEARCH is an extensive freight database prepared at the county level and broken down by commodity and mode. TRANSEARCH data were used in the development of FAF; however, the original source data are useful in moving from FAF zones to more detailed levels of geography used in statewide models.
- **Vehicle Identification and Use Survey (VIUS) –** VIUS data were prepared by the U.S. Census Bureau and provide truck data at national and state levels. The data have been used in statewide freight models to calculate future demand, mode shares, and the cost of truck transportation by mode.

- **Woods & Poole (W&P) Employment Forecasts –** W&P is a private firm that provides economic, employment, household and demographic data at the state, county, and metropolitan levels. The data includes up-to-date figures and forecasts of future conditions. W&P is cited as a source for county population and employment forecasts used in statewide models.

Table 3.1 illustrates how these data sources have been used together in validating some statewide models.

Table 3.1 Data Used for Model Validation

	AL	AZ	CA	FL	TN	TX	UT	WI
Highway Performance Monitoring System (HPMS)		●						●
American Travel Survey (ATS)			●					●
Census Transportation Planning Package (CTPP)			●				●	●
State Data Sources	●		●		●	●		●
National Household Travel Survey (NHTS)				●			●	●
Freight Analysis Framework (FAF)					●			
Reebie/TRANSEARCH					●	●		●

With respect to demographic data for statewide models, a key issue is whether such data should be collected specifically for a statewide model or if secondary source data would suffice. Some statewide models include independently collected socioeconomic data while others borrow data from MPO models and use equivalencies to aggregate demographic information or trip data from MPO zones to statewide traffic analysis zones (TAZs). It is necessary in every case to develop data for the parts of the state outside the urban areas as well. In some states, the nonurban portion is a very high percentage of a state's area.

With respect to traffic count data, a key consideration is whether or not to use traffic counts within urbanized areas as validation targets. Statewide models are usually considered secondary to MPO and regional models for projecting traffic volumes along highway corridors within urbanized areas due to more aggregate networks and zone systems. Thus, while validation statistics may be calculated within urban areas, there is no reason to expect them to be as good as the validation statistics from a well-calibrated regional model. This lack of accuracy might be addressed by focusing on counts for major facilities, major bridge crossings, and external cordon crossings for urban areas.

3.2 Model Validation Techniques

Validation and sensitivity analysis are major components of the modeling process. The validation process determines whether or not a model is reasonably accurate and reliable while sensitivity assesses the ability of the model to forecast changes in travel demand based on changes in assumptions. For the most part the validation process among statewide models is consistent. Many of the same outputs are evaluated to ensure acceptable performance; however, some states carry out more extensive validation processes than others.

One of the most significant differences in validation strategies in the surveyed models is whether to validate the model for each individual step or to focus solely on final outputs of the assignment step. Many of the model documents only referred to validation of assignment outputs, while others, including Florida and Wisconsin, conducted validation for each step of the model. Table 3.2 shows the model output validation statistics analyzed and the step(s) at which each model is reviewed.

Table 3.2 Statewide Model Validation Criteria by Model Step

	AL	AZ	CA	FL	IN	LA	MS	OH	TN	TX	WI
Trip Generation											
Aggregate Trip Rates				●							●
Trips by Purpose				●						●	●
Trip Distribution											
Travel Time		●									●
Average Trip Lengths				●						●	●
Mode Choice											
Auto Occupancy			●	●		●	●			●	
Mode Share			●								
Traffic Assignment											
Area Type Volume-Over-Count)		●	●	●	●				●	●	
Corridor (Volume-Over-Count)					●			●			
District/Region (Volume-Over-Count)			●	●		●	●		●	●	●
Facility Type Volume-Over-Count)	●	●	●	●	●	●	●		●	●	●
Intercity Transit Ridership											●
GEH											●
Long-Distance Trips by Purpose											●
RMSE by Volume Group		●		●	●			●	●		●
R-squared		●									
Screenline (Volume-Over-Count)		●		●	●	●	●	●	●	●	●
Tonnage/Commodity Flows				●						●	●
Total Volume				●							●

	AL	AZ	CA	FL	IN	LA	MS	OH	TN	TX	WI
Truck (Volume-Over-Count)				●							●
VHT (Volume-Over-Count)				●							
VMT (Volume-Over-Count)		●		●	●	●	●	●	●	●	●
Volume Group Volume-Over-Count)	●			●	●			●	●		●

Generally the validation process consists of comparing model estimates with the best available observed data on travel behavior and characteristics. There are many sources of data available for validation. In some cases, the responsible agency may choose to collect its own data, but often this is cost-prohibitive. States may alternately choose to use data already collected as part of a previous study or survey. The National Household Travel Survey (NHTS), Highway Performance Monitoring System (HPMS), Census Transportation Planning Package (CTPP)/American Community Survey (ACS), and TRANSEARCH are all commonly used sources of data for statewide model development and validation. NHTS Add-On surveys have been funded by several states as a cost-effective approach to obtaining new travel behavior data for their statewide models.

Arizona

Like many model validation efforts the current Arizona Statewide Model (SWM) focused on validation of the model outputs at the highway assignment step. The validation process compared summed model volume estimates and observed count data based on seven criteria: cutline performance, coefficient of determination (R^2), travel time, and volume/count comparison based on county, area type, functional class, and volume group. For the volume/count comparisons, modeled volumes were compared to HPMS data to determine percent difference and percent root mean squared error (percent RMSE).

Florida

The Florida SWM segmented the validation process into three levels: system-wide, district-wide, and by corridor.[6] By validating at three different levels, validation issues that affected the entire model were addressed first, then regional issues were addressed, finishing with issues that affected key interstate and intrastate travel corridors. This process included iterative network edits, including the development of speed and capacity tables, addition of toll plazas, acceleration and deceleration links, and adjustment of travel-time penalties as well as adjustments to auto occupancy factors.

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[6] Robert G. Schiffer, Huiwei Shen, Yongqiang Wu, Kenneth D. Kaltenbach, and Thomas F. Rossi, *A Tiered Approach to Validating the Integrated Florida Statewide Model.* Presented at Transportation Research Board 2007 Annual Meeting, January 2007.

The validation process also looked at outputs for all four steps in the model chain to ensure that each was performing at acceptable levels. The Florida SWM was validated using worksheets that compared modeled statistics with observed values, validation benchmarks, and accuracy standards. Statistics reviewed included: number and percent of trips by purpose, aggregate trip rates, average trip lengths, auto occupancy rates, and estimated-over-observed ratios for vehicle miles traveled (VMT) and vehicle hours traveled (VHT), plus volume-over-count ratios by facility type, area type, screenline, specific links, and RMSE. It was decided to use comparative NHTS statistics at the national level instead of Florida respondents only, due to the small sample size for the State at the time. Validation results were compared against statistics from the 2001 NHTS; for future validation efforts Florida will have a larger sample size of the NHTS data for parameter development since the State participated in the 2008 to 2009 NHTS Add-On Survey.

The Florida Statewide Freight Model estimates truck trips as freight and nonfreight components. The statewide freight model was validated using TRANSEARCH data. Truck volume-to-count ratios were reported based on facility type and area type. A freight trip matrix was created from commodity tonnages, and truck counts were used for validation. Part of validating truck assignments was also reviewing bandwidth maps depicting truck volumes by route into and out of the state. Adjustments were made to network assumptions outside Florida to direct trucks to the routes most commonly used by origin and destination.

Indiana

Like many of the other models reviewed, the Indiana Statewide Model was validated by comparing observed traffic counts with estimated flows from the assignment step. The assigned traffic volumes were compared to observed counts on a statewide level and by state highway to separately analyze the performance of key corridors. Volume-over-count ratios were analyzed at a systemwide level by functional class, area type, volume-group range, screenline, and major corridors, along with percent RMSE.

The Indiana SWM also used a tiered level of validation, starting with global validation, then subarea and finally individual links. Two programs were written and added as postprocessing modules to report error statistics, including: percent RMSE, average system error, mean, and percent loading errors, and total and percent VMT errors. After running the module, manual checks were made to identify potential data-related errors for correction.

Tennessee

The Tennessee SWM uses a synthetic origin-destination matrix estimation (ODME) process, and so only the traffic assignment step is validated. As part of the validation process, five different assignment techniques were tested to find the best performing method. The techniques tested were all-or-nothing, incremental, capacity restraint, and two user equilibrium runs with convergence factors of 0.01 and 0.005. After running each type of traffic assignment, observed and estimated results were compared by screenline, VMT and RMSE, leading to a recommendation for the user equilibrium assignment with a convergence factor of 0.01. Travel patterns were validated by aggregating 36 subareas, 20 inside Tennessee and 16 outside. District-to-district volumes were mapped using desire lines for internal-internal (I-I), internal-external (I-E) and external-external (E-E) trip purposes.

The Tennessee freight model was validated by comparing modeled to observed VMT. The observed counts from the Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF) were used for counts outside of Tennessee and TDOT's TRIMS database was used for single- and multi-unit trucks in Tennessee. The truck payload factors were adjusted using TRANSEARCH 2001 data and Federal regulations. Commodity flows were used to determine truck movements. However, the commodity flows did not take into account the amount of empty truck loads that are counted. Therefore an empty truck load adjustment was added based on the assumption that trucks run at 20 percent empty or less.

The freight network was qualitatively verified by mapping commodity flows by bandwidths to depict the volume of commodity flows. E-E truck trips were validated by first locating commodity flows for 25 regions outside of Tennessee and then by comparing VMT from modeled values and TRIMS VMT.

Texas

The Texas Statewide Analysis Model (SAM) was validated during each step of the model process. Trip generation was performed using the same software used by some Texas MPOs models, TRIPCAL5. TRIPCAL5 was developed by the Texas Transportation Institute (TTI). Trip generation results from the model were compared to survey results from TTI. Validation of the trip distribution step was performed by comparing modeled to observed trip length frequency distributions and average trip lengths by purpose. Observed data used for comparison were from the American Travel Survey (ATS).

The assignment validation compared modeled and observed VMT by facility type and area type, and screenline by model volume and ground counts. The facility type comparison did not include arterials and county roads because these facility types, in part, focus on loading trips to higher classified roadways (i.e., those with a greater share of long-distance trips). Counties in states bordering Texas were not included in the validation since the main purpose of those counties was to provide a cushion from the effects of the externals and the unaccounted trips for the regions beyond them.[7]

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[7] Alliance-Texas Engineering Company. *Texas Statewide Analysis Model Theory Report.* Prepared for Texas Department of Transportation, (pp. 4-108) March 10, 2004.

The SAM assigns road, air, and passenger rail trips. As is often the case with forecasting less utilized modes, the air and rail trips account for a small portion of the overall trips and modeled paths. While some of the estimated volumes differ greatly from the observed, the absolute difference is not great and does not affect the overall model performance.

For the freight model validation process, 10 districts were created for trip table summaries, six internal and four external. The external regions represented Louisiana and Arkansas to the east, Oklahoma in the north, New Mexico to the west, and Mexico in the south. The freight model was first validated for the trip generation and trip distribution steps, making changes along the way until estimated tonnage flow values were within acceptable ranges. When validating the trip generation step, the estimated freight productions and attractions were compared to TRANSEARCH totals. Trip distribution was assessed by looking at the reasonableness of district-to-district movements. Once the trip generation and trip distribution steps were validated, the mode choice step was then applied and commodity flows were used to evaluate the model's performance. After both the passenger and freight models were validated separately, autos and trucks were assigned to the network together.

Utah

The Utah SWM validation process looked at the three model steps individually (i.e., excluding mode choice). Adjustments were made to each step to get estimated values within a reasonable range of observed NHTS statistics. Production and attraction rates were modified iteratively for the trip generation step. Friction factors were adjusted and K-factors were added to the trip distribution step. Validation of the traffic assignment step included extensive network checks, review of traffic counts, and adjustment to speed and capacity tables, conversion factors, and time/distance weights.

Three screenline levels were included in the model: large, medium, and MPO. The large screenlines cover external routes, medium screenlines represent competing facilities, and MPO screenlines were created to sum trips into and out of MPO regions.

The freight model validation focused on three elements: 1) adjustment of trip rates, 2) average trip lengths, and 3) trip distribution patterns. The initial run used parameters from the Quick Response Freight Manual causing a considerable over-assignment in VMT statewide. The next step was to change the coefficients until estimated truck VMT was closer to observed VMT. After this, friction factors and K-factors were applied to fix trip lengths and distribution patterns.

Wisconsin

Each step of the Wisconsin SWM was validated using the overall approach outlined in the FHWA *Model Validation and Reasonableness Checking Manual*.[8] The validation process included network and zone data checks, reasonableness, and sensitivity checks of parameters and input variables, and comparison of base-year and independent data sets.

The zonal data are based on Wisconsin DOT's City/Village/Town database structure in non-MPO regions, and is based off of aggregations of urban models within urban regions. The Wisconsin-based highway network is derived from the Wisconsin System for Local Roads (WISLR) and the State Trunk Highway (STN) System. The National Highway Planning Network was used for roadways external to Wisconsin.

Validation of trip generation included use of trip production rates derived from NHTS Add-On data and percentages were compared to acceptable ranges in the *Model Validation and Reasonableness Checking Manual*. Validation of the trip distribution step included comparisons of average trip lengths, coincidence ratios, and percent intrazonal trips. The mode choice step focused on long-distance intercity mode shares. The values generated were consistent with referenced materials on intercity travel.

Validation of the highway assignment step looked at traditional metrics as well as the GEH statistic. VMT, RMSE, and screenline differences also were summarized by facility type and volume ranges. The GEH statistic[9] is calculated based on the absolute and percent difference of modeled and observed data, in an effort to avoid inadequacies that may occur when comparing traffic volume percentages:

$$GEH = \sqrt{\frac{(AssignedVolume - Count)^2}{((AssignedVolume + Count)/2)}}$$

The Wisconsin freight model was validated in a similar way to the passenger model, looking at the four steps individually. Freight Analysis Framework (FAF) data were used to obtain average trip lengths and commodity data, and estimated VMT was compared with the Highway Performance Monitoring System (HPMS) and Traffic Analysis Forecasting Information System (TAFIS).

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[8] Barton-Aschman Associates, Inc. and Cambridge Systematics, Inc. *Model Validation and Reasonableness Checking Manual*. Prepared for Travel Model Improvement Program/ Federal Highway Administration, February 1997.

[9] Cambridge Systematics, Inc. and HNTB. *Wisconsin Statewide Model – Passenger and Freight Models.* Prepared for Wisconsin Department of Transportation, September 2006.

3.3 Structural Metrics

This subsection examines typical structural characteristics for statewide models such as zone systems, network structure, and demographic data. Statewide models vary considerably by size of the state, density of development, and level of detail sought in the model outputs. Statistics cited in this report have been culled primarily from technical reports describing the features and results of each model. Metrics are thus largely limited to those documented in reports. Not every metric summarized in this section was documented for each model document reviewed. Therefore, each table of metrics cites a different number of statewide models. A complete bibliography of all documents reviewed for this study is included in Appendix A.

In addition to statewide model technical reports, the authors reference a number of guidance documents as a way of comparing model metrics to numbers typically referenced in modeling literature. These guidance documents include the following:

- *FSUTMS-Cube Framework Phase II: Model Calibration and Validation Standards Final Report*[10] – 2008 Model Calibration and Validation Standards Final Report prepared for the Florida DOT based on results from models throughout the U.S. Typical ranges for these statistics are included in some of the tables found in this subsection, and often referenced as FDOT High and FDOT Low.
- *NCHRP Report 365* (noted earlier) – NCHRP Low and High statistics likewise depict a range of typical values cited in this report.
- *Iowa DOT Peer Review* – Summary of peer exchange held in Iowa to identify state of the practice considerations for model enhancements in this state.
- *Michigan DOT* – Summary of documented model validation standards used by the Michigan DOT to assess model performance.

Table 3.3 presents a summary of input data metrics including the number of TAZs, number of links, population, households, employment, and several calculated ratios using these statistics. The socioeconomic data used to calculate ratios found in the last four rows of Table 3.3 are from Census 2000 figures, while statistics in the first three rows were quoted from model documents.

[10] Cambridge Systematics, Inc. *FSUTMS-Cube Framework Phase II: Model Calibration and Validation Standards Final Report.* Prepared for Florida DOT Central Office, October 2008.

Table 3.3 Socioeconomic Ratios for Statewide Models

	Statewide Model Results																				Guidance Documents			
																					FDOT		Iowa DOT	
	AL	DE	FL 2000	IN	KY	LA	MD	MA	MS	MO	NJ	OH	OR	RI	TN	TX	UT	VA	VT	WI	Low[a]	High[a]	Low[c]	High[c]
Number of Zones	1,081	908	4,000	4,720	4,753	1,313	1,739	3,069	3,305	2,392	2,813	4,248	145	1,257	1,397	4,742	3,247	1,078	698	1,875	–	–	–	–
Number of Links	4,607	10,047	–	34,500	77,272	–	167,150	–	–	–	44,000	–	–	–	–	60,500	26,000	246,935	12,439	200,000	–	–	–	–
Ratio of Links per Zone	4.26	11.06	–	7.31	16.26	–	96.12	–	–	–	15.64	–	–	–	–	12.76	8.01	229.07	17.82	106.67	–	–	–	–
Persons per Household or DU	2.26	2.28	2.19	2.4	2.31	2.42	2.47	2.42	2.45	2.29	2.54	2.55	2.36	2.38	2.33	2.56	2.91	2.44	2.07	2.31	2.00	2.70	–	–
Employment/Population	0.43	0.49	0.44	0.49	0.45	0.42	0.5	0.5	0.42	0.48	0.47	0.48	0.48	0.48	0.47	0.45	0.47	0.5	0.52	0.51	0.35	0.75	–	–
Autos/Household or DU	1.6	1.5	1.38	1.68	1.57	1.4	1.56	1.44	1.56	1.56	1.48	1.76	1.66	1.5	1.65	1.54	1.85	1.7	1.43	1.59	1.75	2.10	–	–
Population/TAZ[b]	4,113	863	3,995	1,288	850	3,403	3,045	2,068	860	2,339	2,991	2,673	23,595	1,100	4,656	4,533	694	4,474	872	2,861	3,000		1TAZ/1k Population	

Notes:

[a] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[b] Population/TAZ reflects only internal zones where these numbers are available; total number of zones used where the split of internal versus external zones is unknown.

[c] Iowa DOT Peer Review – U.S. DOT Travel Model Improvement Program.

These statistics provide only a general idea regarding the range of socioeconomic ratios and zone densities experienced in states with statewide models. Clearly, when developing or updating a statewide model, demographic ratios in the model should be compared against independent source estimates, where possible.

Ratios of links per zone vary greatly in statewide models, not surprisingly, from a low of 4.26 in Alabama to a high of 156.09 in the Virginia "micro" statewide model focused on statewide internal trips. The Alabama network is a fairly simple "stick network" without adjacent states whereas the Virginia model has a very detailed network, including major corridors across the United States for the purposes of simulating freight flows. In retrospect, lane-miles per TAZ might be a more reliable measure (were lanes miles available for more of these models) than links per zone since some networks use nodes to generate network shapes.

Average population per TAZ in statewide models ranges from 694 in Utah to a high of nearly 24,000 in an earlier version of the Oregon SWM (according to a report published in 1999, including the number of TAZs[11]). Based on Census 2000 data, persons per household (or dwelling unit) range from a low of 2.19 in Florida (impact of retirees) to a high of 2.91 in Utah (high birth rates/large family sizes). Employees per household computed from Census 2000 data fall mostly into a range documented in a recent Florida DOT study on calibration and validation standards and benchmarks (based on studies within and outside Florida). Autos per household reported by the Census hover close to 1.5 to 2.0 autos per household, which is similar to ratios reported in models and guidance documents. In states near the upper or lower ends of these ranges, it might be erroneous to borrow trip rates from other statewide models.

Ratios of population per TAZ are based on internal zones, wherever it was easy to distinguish internal zones from those located outside the state of concern. Elsewhere, the total number of TAZs was used. Ratios of links per zone reflect the entire model as statistics were unavailable on internal links only. The next subsection identifies likely ranges of statistical values related to validating a statewide model, with a focus on model outputs.

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[11] Parsons Brinkerhoff Quade & Douglas. *Development and Calibration of the Statewide Land Use-Transport Model.* Prepared for the Oregon Department of Transportation, February 1999.

3.4 REASONABLENESS CHECKS

The criteria for assessing the reasonableness of a model are necessarily more variable for statewide models than urban models. Models of small states may use criteria that are similar to urban and regional models, but models that cover much larger areas have more aggregate zone and network structures and the reasonableness criteria must be kept consistent with the resulting lower level of detail. This subsection presents a variety of reasonableness criteria that have been used by different states in assessing the performance of their statewide models.

As with the previous subsection, several guidance documents are referenced in tables of metrics presented here. Additionally, travel survey statistics are referenced from the following:

- **National Household Travel Survey –** Survey statistics from the 2001 NHTS;
- **Wisconsin NHTS Add-On –** High- and low-end survey statistical ranges as reported in the State's Add-On survey only; and
- **Other States –** Where available and documented, travel survey statistics are referenced for Delaware, Indiana, Louisiana, Massachusetts, Utah, and Virginia. Many of these were roadside survey interviews.

Trip Generation

Table 3.4 presents a summary of aggregate trip rates identified in statewide model documentation. These statistics include trips per household, population, employment, and TAZ, and were calculated based on the total number of trips reported for each model. Only six statewide model reports documented person trips per population, and these ranged from a low of 1.95 for California intra-regional trips in the High-Speed Rail model to a high of 4.25 in Wisconsin. Meanwhile person trips per household ranged from 8.21 to 10.33, which is similar to statistics cited in guidance documents such as NCHRP 365, 2001 NHTS results, and the previously referenced Florida DOT Calibration Report.

Another useful statistic used in validating trip generation models is the percent of trips by purpose. As shown in Table 3.5, based on available documented results, statewide models exhibit similar percent home-based work, nonwork, and nonhome-based trips to ranges found in guidance documents of urban and regional statistics. While statewide models often include separate long-distance trip purposes, such trips are typically generated and summarized separately from the more traditional model purposes. Comparisons among statewide models indicate that the predominant long-distance purposes are leisure, tourist, and nonwork.

Table 3.4 Aggregate Trip Rates for Statewide Models

	Statewide Model Results						Guidance Documents			
							FDOT		NCHRP	
	CA[d]	FL 2000	MA	UT	VA	WI	Low[a]	High[a]	Low[b]	High[b]
Person Trips/TAZ	–	13,026	7,489	2,134	16,197	12,788	–	15,000	–	–
Person Trips/Person	1.95	3.26	3.62	3.08	3.62	4.25	3.3	4	–	–
Person Trips/Household (DU)[c]	5.41	8.21	9.4	8.94	9.5	10.33	8	10	6.8	12.4
HBW Person Trips/Household	–	–	1.73	1.38	1.38	1.73	–	–	–	–
Person Trips/Employee	4.41	7.38	7.26	6.54	7.23	8.76	–	–	1.29	1.4

Notes:

[a] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[b] 1998 NCHRP Report 365 Travel Estimation Techniques for Urban Planning, trips/HH.

[c] Reported statistics are for motorized trips only.

[d] California High Speed Rail Model, figures based on intraregional trips.

Also, because statewide models usually generate freight trips separately from passenger trips, truck trip purposes are not usually summarized along with person trip purposes. Truck trip purposes are usually equivalent to commodity groups which vary greatly depending on predominant industries in different parts of the United States, thus limiting transferability as well. The exceptions to this are found where simplified truck models (e.g., Alabama) have been used in place of more intricate freight models. In these cases, truck trips are often generated alongside other trip purposes, similar to many urban and regional models. Additional discussion on freight and truck trips in statewide models can be found in Section 5.0 of this report.

Trip Distribution

With an emphasis on longer-distance trips, including visitors and trucks, it stands to reason that average trip lengths in statewide models would be higher than those typically reported at the MPO level. As summarized in Table 3.6, average trip lengths by purpose vary widely by state. Average trip lengths (in minutes) for home- and nonhome-based purposes in statewide models fall within the higher end of ranges typically found in MPO models, as reported in guidance documents also found in this table. Conversely, average trip lengths for the long-distance trip purposes, while unique to statewide models, are clearly much longer than average trip lengths reported for MPO models in the guidance documents. Observed data on average trip lengths are found in the survey data columns of Table 3.6.

Table 3.5 Trip Purpose by Percentage Found in Statewide Models[a]

	Statewide Model Results							Travel Survey Data					Guidance Documents			
									Wisconsin		NHTS		FDOT		NCHRP	
Trip Purpose	**AL**	**FL 2000**	**LA**	**MA**	**MS**	**UT**	**VT**	**DE**	**Short-Distance[b]**	**Long-Distance[b]**	**Urban[c]**	**Rural[c]**	**Low[d]**	**High[d]**	**Low[e]**	**High[e]**
Home-Based Work	19.19%	19.14%	19.00%	18.41%	16.06%	15.50%	23.30%	34.00%	18.04%	–	11.15%	11.36%	12.00%	24.00%	17.00%	23.00%
Home-Based Nonwork	46.22%	55.47%	47.70%	52.06%	49.17%	45.10%	–	–	–	–	–	–	45.00%	60.00%	–	–
Home-Based Other	–	27.92%	47.70%	19.38%	49.17%	45.10%	32.20%	18.00%	9.47%	–	21.52%	21.73%	14.00%	28.00%	52.00%	60.00%
Home-Based Shop	–	15.76%	–	11.73%	–	–	12.80%	17.00%	15.26%	–	22.94%	20.40%	10.00%	20.00%	–	–
Home-Based Social/Recreation	–	11.79%	–	13.95%	–	–	–	10.00%	11.91%	–	13.78%	12.87%	9.00%	12.00%	–	–
Home-Based School	–	–	–	7.00%	–	–	5.80%	–	19.03%	–	–	–	5.00%	8.00%	–	–
Nonhome-Based	–						25.80%	–	–	–	–	–	–	–	–	–
Nonhome-Based Work	–	–	–	10.27%	–	–	–	11.00%	–	–	–	–	–	–	–	–
Nonhome-Based Nonwork	–	–	–	14.41%	–	–	–	6.00%	–	–	–	–	–	–	–	–
Other	21.80%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Truck	7.79%	–	1.70%	–	–	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Business	–	–	0.20%	2.84%	0.11%	–	–	–	–	24.80%	–	–	–	–	–	–
Long-Distance Tourist	–	–	0.10%	0.27%	0.00%	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Work	–	–	–	1.05%	–	0.30%	–	–	–	–	–	–	–	–	–	–
Long-Distance Nonwork/Other	–	–	0.30%	–	0.11%	0.60%	–	–	–	–	–	–	–	–	–	–
Internal-External Business	–	–	–	–	0.44%	–	–	–	–	–	–	–	–	–	–	–
Internal-External Tourist	–	–	–	–	0.44%	–	–	–	–	–	–	–	–	–	–	–
Internal-External Other	–	–	–	–	0.77%	–	–	–	–	–	–	–	–	–	–	–
External	0.75%	–	–	0.67%	–	–	–	–	–	–	–	–	–	–	–	–

Notes:

[a] Percentages based on proportion of total trips.

[b] Wisconsin short- and long-distance trips from the 2001 NHTS Add-On.

[c] As calculated from 2001 NHTS data (full national sample) by Cambridge Systematics, Inc. and documented in 2006 Model Parameters Final Report for the Florida DOT (see Bibliography for all document titles).

[d] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S..

[e] NCHRP Report 365 Travel Estimation Techniques for Urban Planning.

Table 3.6 Average Trip Lengths Found in Statewide Models
Trip Lengths in Minutes

	Statewide Model Results									Travel Survey Data						Guidance Documents			
																FDOT		NCHRP	
Trip Purpose	**FL 2000**	**LA**	**MA**	**OH[d]**	**RI**	**TX**	**UT**	**VA**	**VT**	**IN**	**LA**	**MA**	**VA**	**UT**	**NHTS[a]**	**Low[b]**	**High[b]**	**Low[c]**	**High[c]**
Home-Based Work	18.38	17.3	23.05	11	21.59	16	17.79	14.6	21.97	20.11	–	24.14	16.40	18.20	24.46	12.00	35.00	11.20	35.40
Home-Based Other/Nonwork	16.22	12.2	14.57		15.64	9.06	12.98	10.8	18.56	14.56	–	14.56	15.70	13.90	16.12	8.00	20.00	10.40	17.30
Home-Based Shop	16.77	–	15.06	8.2	–	–	–	–	20.78	–	–	14.64	–	–	24.22	9.00	19.00	8.60	18.70
Home-Based Social/Recreation	15.55	–	16.19	8.2	–	–	–	–	–	–	–	16.70	–	–	18.35	11.00	19.00	–	–
Home-Based School	–	–	13.93		–	–	–	–	19.24	–	–	13.59	–	–	–	7.00	16.00	8.90	15.90
Nonhome-Based	13.06	9.3	–		14.45	9.68	12.37	23.17	14.49	14.41	–	–	22.50	13.40	19.86	6.00	19.00	8.10	17.10
Nonhome-Based Work	–	–	17.91		–	–	–	–	–	–	–	17.44	–	–	–	–	–	–	–
Nonhome-Based Other	–	–	15.62		–	–	–	–	–	–	–	15.20	–	–	–	–	–	–	–
Other	–	–	–	7.1	–	10.83	–	–	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Business	134.67	166	–		–	–	–	127.13	–	–	165.00	–	–	–	–	–	–	–	–
Long-Distance Personal Business	–	–	–		–	–	–	124.58	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Tourist	–	172	–		–	–	–	126.67	–	–	192.00	–	–	–	–	–	–	–	–
Long-Distance Work	–	–	–		–	200.82	89.54	–	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Nonwork/Other	–	164	–		–	199.71	81.73	–	–	–	168.00	–	–	–	–	–	–	–	–
Internal-External Business	–	–	–		–	–	51.26	–	–	–	–	–	–	–	–	–	–	–	–
Internal-External Other	–	–	–		–	–	55.49	–	–	–	–	–	–	–	–	–	–	–	–
Internal-External Short-Distance	42.82	–	–		–	30	–	–	–	–	–	–	–	–	–	–	–	–	–
Internal-External Long-Distance	–	–	–		–	125.75	–	–	–	–	–	–	–	–	–	–	–	–	–

Notes:

[a] As calculated from 2001 NHTS data (full national sample) by Cambridge Systematics, Inc. and documented in 2006 Model Parameters Final Report for the Florida DOT.

[b] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[c] NCHRP Report 365 Travel Estimation Techniques for Urban Planning.

[d] Ohio data is in miles, not minutes.

Also related to trip distribution is the percent of intrazonal trips by purpose, which one would expect to be generally higher in statewide models that typically have larger zones than MPO models. Table 3.7 reports intrazonal percentages that were available from statewide model documentation. In comparing the five models for which such data were available against statistics found in the guidance documents, the percent of intrazonal trips was found to be considerably higher in statewide models than levels found in most MPO models. This reflects both the larger zone sizes and the lower density of network links found in statewide models.

Table 3.7 Percent Intrazonal Trips Found in Statewide Models

	Statewide Model Results					Survey Data	Guidance Documents			
							FDOT		Iowa DOT	
Trip Purpose	**FL 2000**	**MA**	**PA**	**UT**	**WI**	**MA**	**Low[a]**	**High[a]**	**Low[b]**	**High[b]**
Home-Based Work	9.40%	6.30%	–	5.50%	29.20%	5.10%	1.00%	4.00%	–	–
Home-Based Nonwork	17.40%	–	–	–	–		–	–	–	–
Home-Based Shop	15.60%	16.50%	–	–	41.00%	15.10%	3.00%	7.00%	–	–
Home-Based Social/ Recreation	37.30%	15.30%	–	1.60%	37.40%	13.10%	3.00%	9.00%	–	–
Home-Based School	–	–	–	–	51.50%	13.30%	4.00%	10.00%	–	–
Home-Based Other	25.20%	17.00%	–	8.50%	53.60%	16.80%	10.00%	12.00%	–	–
Nonhome-Based	–	–	–	8.30%	54.40%		5.00%	9.00%	–	–
Nonhome-Based Work	–	18.40%	–	–	–	19.70%	–	–	–	–
Nonhome-Based Other	–	19.20%	–	–	–	19.80%	–	–	–	–
TOTAL	**19.90%**	**–**	**37.70%**	**–**	**–**		**3.00%**	**5.00%**	**3.00%**	**5.00%**

Notes:

[a] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[b] Iowa DOT Peer Review – U.S. DOT Travel Model Improvement Program.

Auto Occupancy

In terms of auto occupancy rates, much like earlier findings on average trip lengths, statewide models are not very different from MPO models for home- and nonhome-based trip purposes. Although, as reported in Table 3.8, auto occupancies are higher for the unique long-distance trip purposes found in statewide models, when compared to typical urban auto occupancies reported in the guidance documents and NHTS survey data. The authors of this document attribute higher auto occupancies for long-distance trips to the increased likelihood of families, friends, and colleagues typically making long-distance recreational and business trips together in a single vehicle.

Table 3.8 Average Auto Occupancy Found in Statewide Models

	Statewide Model Results								Survey Data	Guidance Documents			
										FDOT		NCHRP	
Trip Purpose	CA	FL 2000	KY	LA	MS	RI	TX	UT	NHTS[a]	Low[b]	High[b]	Low[c]	High[c]
Home-Based Work	1.19	1.1	–	1.15	1.1	1.12	–	–	1.10	1.05	1.10	1.11	1.13
Home-Based Nonwork	–	–	–	–	–	–	–	–	–	–	–	–	–
Home-Based Other	1.54	1.7	–	1.78	1.65	1.56	–	–	1.70	1.65	1.95	1.65	1.67
Home-Based Shop	–	1.8	–	–	–	–	–	–	1.80	1.50	1.80	1.44	1.48
Home-Based Social/ Recreation	1.49	1.94	–	–	–	–	–	–	1.94	1.70	1.90	1.66	1.72
Nonhome-Based	–	1.71	–	1.79	1.56	1.56	–	–	1.71	1.60	1.90	1.64	1.68
Work	–	–	–	–	–	–	1.33	–	–	–	–	–	–
Nonwork	–	–	–	–	–	–	2.06	–	–	–	–	–	–
Long-Distance Business	1.19	–	1.8	1.86	1.39	–	–	1.82	–	–	–	–	–
Long-Distance Tourist	–	–	3.31	3.44	2.55	–	–	2.69	–	–	–	–	–
Long-Distance Work	–	–	2.43	–	–	–	–	–	–	–	–	–	–
Long-Distance Recreation	1.73	–	–	–	–	–	–	–	–	–	–	–	–
Long-Distance Nonwork/ Other	1.31	–	–	2.64	2.05	–	–	2.69	–	–	–	–	–
Internal-External Business	–	–	–	–	1.5	–	–	–	–	–	–	–	–
Internal-External Tourist	–	–	–	–	2.55	–	–	–	–	–	–	–	–
Internal-External Other	–	–	–	–	2.26	–	–	–	–	–	–	–	–

Notes:

[a] As calculated from 2001 NHTS data (full national sample) by Cambridge Systematics, Inc. and documented in 2006 Model Parameters Final Report for the Florida DOT.

[b] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

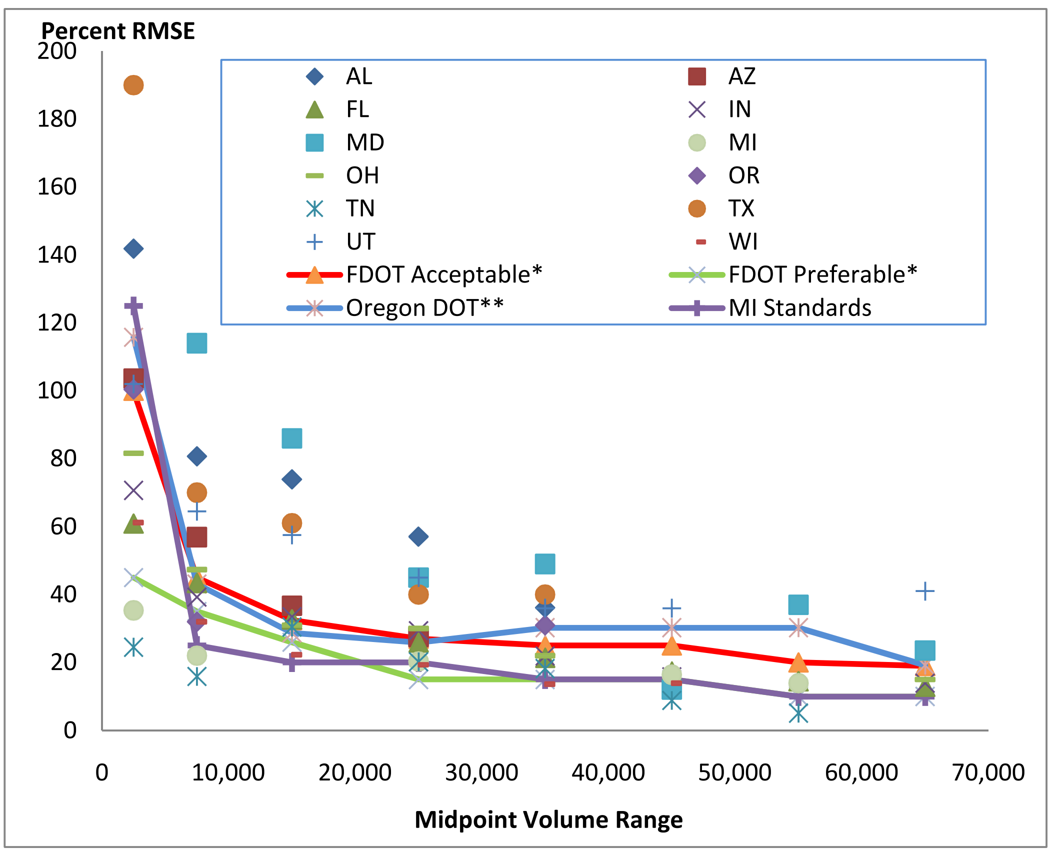
[c] NCHRP Report 365 Travel Estimation Techniques for Urban Planning.

Trip Assignment

Finally, this study looked at what reasonable accuracy levels would be for traffic assignments in statewide models. Relatively few statewide models are multi-modal and auto volumes are by far the most important model output. Few statewide models have documented percent root mean squared error (RMSE) statistics. In order to increase the representative number of models with traffic assignment statistics, percent error statistics also were summarized separately, sometimes for different models than those tracking percent RMSE. Percent RMSE and percent error both assess the accuracy of base-year assignment volumes against observed traffic estimates (i.e., traffic counts).

Table 3.9 depicts ranges of percent RMSE found in statewide models compared against published accuracy standards. Such comparisons are complicated by differing volume ranges used to summarize percent RMSE. To add clarification to these comparisons, Figure 3.1 shows the distribution of the percent RMSE midpoints in comparison with the Florida DOT and Oregon DOT acceptable ranges. However, based on the 12 models with such statistics documented, it appears that statewide models generally achieve most base-year percent RMSE accuracy standards established for urban and regional models.

Figure 3.1 Statewide Model RMSE Distribution by State



At the same time, it should be noted that some of these models exhibit higher percent RMSEs in the lower volume groups than typical accuracy standards. The authors of this report attribute this in part to the greater number of low-volume, rural highways found in statewide models than in typical MPO models. Another factor to consider in reviewing RMSE statistics is that statewide model documents tend to dissect low-volume groups into more categories than found in typical MPO models. Other factors include inconsistencies between zone and network systems and lack of detail in some statewide model networks. Since there are relatively few percent RMSE standards available by volume group, accuracy standards for percent error by volume range also are provided in Table 3.9.

Percent assignment error statistics were typically documented in statewide models by facility type (and sometimes area type), similar to MPO models and available accuracy standards. For many of these models, volume-over-count ratios were converted to percent error statistics for comparison against established accuracy standards found in the guidance documents. As depicted in Tables 3.10 and 3.11, statewide models seem to achieve documented accuracy standards for assignment error by area type and facility type.

3.5 Relationships between Urban and Statewide Models

The key purpose of statewide models is to estimate intercity and rural travel demand, whereas urban and regional models have focused on travel demand within and through a specific region. Often depending on the purpose of the model or the amount available data, the level of detail of a network varies greatly. Some statewide models include as many roads in the network possible, while others include only select roads that are necessary for the intended analysis. While there is no set rationale for how states determine which road, rural and/or urban, to include, it typically comes down to the intended purpose of the statewide model.

In some cases forecasts of intra-urban trips were excluded from statewide models to focus on intercity and rural trips, and to avoid duplication of MPO forecasts within urban areas. In other cases urban models were included as a supplement to the statewide models, and in the case of New Jersey five regional models were pieced together to create a statewide model. The entire area of New Jersey is included in metropolitan areas; so when need arose for a New Jersey Statewide Model, the developers turned to existing models to assemble a single comprehensive statewide model.

Table 3.9 RMSE Statistics from Statewide Models

	Statewide Model Results												Guidance Documents			
													FDOT			
Range	**AL**	**AZ**	**FL 2000**	**IN**	**MD**	**MI**	**OH**	**OR**	**TN**	**TX**	**UT**	**WI**	**Acceptable[a]**	**Preferable[a]**	**Oregon DOT[b]**	**Michigan[c]**
1 to 5,000	141.8	103.6	60.9	42.29-99.06	–	35.33	115-58	100.33	27.2-21.8	90-290	57-147	41.82-80.61	100	45	115.76	50-200%
5,000 to10,000	80.7	56.9	43.4	35.52-42.97	114	22	55-42	32	15.9	70	53-76	32	45	35	43.14	25%
10,000 to 20,000	65.5-82.4	36.7	32.7	31.33-35.6	86	–	36-24	–	25.4-35.5	61.0[d]	34.0-81.0	22.3	30.0-35.0	25.0-27.0	28.73	20%
20,000 to 30,000	57.1	27.5	25.9	29.34	45	20.3	25-28	–	20.2	40.0[d]	45	19.33	27	15	25.84	20%
30,000 to 40,000	36.2[e]	–	21.4	21.93	49	–	23	31	18.2	40.0[d]	36	13.62	25	15	30.25	15%
40,000 to 50,000	–	–	17.4	15.74	12	16.4	–	–	8.8	–	36	13.91	25	15	30.25	15%
50,000 to 60,000	–	–	14.5	–	37	13.9	17	–	5.1[f]	–	–	–	20	10	30.25	10%
> 60,000	–	–	10.9-14.9	13.22-14.6	23.5	–	11	–	–	–	41	–	19	10	19.2	10%
Total	**82.2**	**56**	**32.6**	**39.42**	**–**	**–**	**35**	**–**	**–**	**90**	**49**	**39.21**	**45**	**35**		

Notes:

[a] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[b] As documented in 1995 Travel Demand Model Development and Application Guidelines for Oregon DOT.

[c] Percent Deviation from Counts – Michigan DOT Urban Model Calibration Targets, 1993.

10,000 to 25,000 and 25,000+ ranges used in Texas model reference.

[e] 25,000+ range used in Alabama model reference.

[f] 50,000+ range used in Tennessee model reference.

Table 3.10 Percent Assignment Error for Statewide Models

	Statewide Model Results								Guidance Documents					
									Ratios from Urban/ Regional Models[a]		FDOT			
Facility Type	**AL**	**FL 2000**	**MA**	**MI**	**OH**	**TX**	**VT**	**WI**	**Low**	**High**	**Acceptable (+/-)[a]**	**Preferable (+/-)[a]**	**Michigan DOT (+/-)[b]**	**FHWA (+/-)[c]**
Interstate	–	–	–	1.00	–	0.84	0.98	0.94	–	–	7.00%	6.00%	6.00%	7.00%
Freeway	1.01	0.98	1.01	–	0.96	–	–	1.08	0.86	1.15				
Expressway	–	–	–	–	–	–	–	1.05						
U.S. Highway	–	–	–	–	–	1.03	–	–	–	–	15.00%	10.00%	–	10.00%
State Highway	–	–	–	–	–	0.55	–	–	–	–			–	
Arterials	–	–	0.97	–	–	–	–	–	–	–			–	
Principal Arterial	1.05	–	–	–	–	–	1.02	0.99	0.89	1.06			7.00%	
Major Arterial	–	1.01	–	0.99	0.9	–	–	–	–	–			–	
Minor Arterial	0.94	1.03	–	1.03	1.09	–	0.95	1.06	0.77	1.07			10.00%	15.00%
Collector	0.87	1.01	0.97	–	1.17	–	1.11	–	0.37	1.05	25.00%	20.00%	20.00%	25.00%
Major Collector	–	–	–	0.88	–	–	0.93	–	–	–				
Minor Collector	–	–	–	0.95	–	–	1.02	–	–	–				

Notes:

[a] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

[b] Michigan DOT Urban Model Calibration Targets, 1993.

[c] 1997 FHWA Model Validation and Reasonableness Checking Manual (same accuracy standards referenced in several other documents as well). (In guidance documents, seven percent assignment error = volume-over-count ratio of 0.93 to 1.07.)

Table 3.11 Percent Assignment Error for Statewide Models by Area Type

	Statewide Model Results										Ratios from Urban/ Region Models	
											FDOT	
Area Type	AZ	CA	FL 2000	IN	LA[a]	MA	MI[a]	RI	TN	VT	Low (+/-)[b]	High (+/-)[b]
Urban	1.05	1.14	–	0.98	–	1.00	1.00	1.00	1.03	1.03	–	–
Suburban	–	1.11	–	0.92	–	1.00	–	–	–	–	–	–
Rural	1.20	0.94	1.06	1.03	0.96	0.96	1.04	1.12	0.93	0.94	0.70	1.12
CBD	–	–	0.97	–	–	–	–	–	–	–	0.88	1.20
Fringe	–	–	1.02	–	–	–	–	–	–	–	0.90	1.03
Residential	–	–	1.00	–	–	–	–	–	–	–	0.97	1.04
OBD	–	–	0.90	–	–	–	–	–	–	–	0.91	1.06
Major Employment Center	–	–	–	1.02	–	–	–	–	–	–	–	–
MPO	–	–	–	–	1.13	–	–	–	–	–	–	–
Census Place	–	–	–	–	1.02	–	–	–	–	–	–	–

Notes:

[a] Volume-over-count was calculated using VMT instead of AADT (i.e., estimated VMT/observed VMT).

[b] As documented by Cambridge Systematics, Inc. in 2008 Model Calibration and Validation Standards Final Report for the Florida DOT, results from models throughout the U.S. (see Bibliography for all document titles).

The Louisiana and Mississippi statewide models focus on intercity and rural travel for auto and freight, and exclude intra-urban trips. The urban areas within these states have separate models, and the model developers felt that including the urban areas would cause an unnecessary duplication of forecasts. Instead the urban models were used to provide internal-external trips for the statewide models, and the statewide models provided urban models with external-internal trips. However, the California Statewide High-Speed Rail Model estimates travel demand for interregional and intraregional trips for numerous modes, including high-speed rail, public transit, autos, and truck. Therefore, it was essential to incorporate data from the four largest MPOs included in the statewide model.

Statewide models are sometimes used when estimating or validating urban models. Urban and regional models often rely on local travel surveys to validate model forecasts. Many of these travel surveys focus on short-distance trip purposes and do not include long-distance external trips; which are the general focus of statewide models. Since statewide models undergo their own validation process based on different information than urban models, it is reasonable to use statewide model results as a source for base-year and forecasted long-distance or external trip counts.

3.6 Model Forecasting and Sensitivity Testing

The authors of this document have found that application of statewide models in forecasting travel demand requires more comparative assessment with alternate sources than accomplished in typical urban and regional model applications. While best modeling practice should always include an assessment on the reasonableness of resulting forecasts, urban and regional models are validated, applied, and updated with sufficient frequency that "out of the box" results should not always require comparisons against multiple forecasting tools.

Statewide models are validated, applied, and updated less frequently than urban and regional travel demand models though. Unless dealing with a very small state, where all residents are within a single metropolitan area, model "ownership" is generally in the hands of the state's DOT with MPO staff only minimally aware of the statewide model and how it can improve their forecasting process. The process of updating statewide model socioeconomic estimates and forecasts differs from state to state and might only involve MPOs once every 5 to 10 years. Statewide models also typically include large rural territories that have no formal transportation planning organizations, leaving the state DOT to update model assumptions in these areas. Sparse networks and zone systems, typical of statewide models, have an impact on model accuracy as well.

In light of this context, it becomes crucial to compare statewide model forecasts with other sources such as extrapolated traffic count trends and other urban, regional, and statewide models with territory overlapping the statewide model in question. The authors of this report recommend three comparative assessments that should be made against statewide model forecasts, as follows:

- **Traffic Count Extrapolations –** Most state DOTs have electronic traffic count databases that can be easily accessed to track historic trends and extrapolate linear growth rates at specific count stations to targeted future horizon years.
- **Comparisons with Other Models –** Comparisons between statewide and MPO models at study area boundaries and along isolated network links (e.g., bridges, mountain passes, etc.) can actually improve the quality of forecasting for both statewide and regional models.
- **Assess Model Sensitivity –** Model sensitivity, or elasticity, can be determined by evaluating the impact of changes in supply (represented by model inputs such as roadway capacity) on resulting travel demand forecasts. A 2003 Utah DOT study on model sensitivity[12] found that elasticity is often calculated using change in lane-miles to represent supply and change in vehicle-miles traveled to represent demand with acceptable resulting elasticities in the range of 0.3 to 1.0 using a formula similar to this:

$$Elasticity = \frac{\Delta VMT}{\Delta LaneMiles}$$

After assessing the reasonableness and sensitivity of statewide model forecasts, the modeler should address perceived problems. Lack of model sensitivity will likely require adjustments to assumptions used in model validation and revisions to the base-year model. Until a sufficient body of research is available on elasticity levels for statewide models, ranges referenced in the aforementioned study for the Utah DOT should suffice.

There is no patent approach to resolving differences among forecasts from a range of sources. Discussions with MPO staff responsible for maintaining any regional models used in comparison with statewide model forecasts might help ascertain the level of confidence in regional model forecasts at specific corridor locations. R^2 values should be calculated for linear traffic count growth curves to determine the goodness of fit, in conjunction with an understanding of how trends have or will be impacted by capacity changes to the corridor of interest or nearby competing transportation routes.

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[12] Cambridge Systematics, Inc. in Association with Fehr & Peers. *Wasatch Front Regional Council Model Sensitivity Testing Final Report*. Prepared for Utah Department of Transportation, November 2003.

3.7 Conclusions/Summary

One common finding during preparation of this report is that available documentation of statewide model validation is rather sparse. While data sources and structural components are generally documented (and similar) among statewide models, relatively little information is provided with respect to model output statistics and benchmarks for determining model reasonability and validity. Other than occasional comparisons against other, similar statewide models, there are few documented validation tests unique to statewide models.

One possible explanation for this is that since statewide models include a larger share of low-volume roadways that are difficult to simulate, model developers are reluctant to publish results that would be considered less than satisfactory in the context of an urban or regional model. Since different standards have not yet been developed for statewide models, there is some confusion as to whether or not urban and regional model standards are relevant to statewide model validation. However, this study shows that most statewide models that do publish validation statistics exhibit relatively similar ranges of metrics to those reported in MPO model guidance documents. A general lack of observed data on long-distance trip-making is hindering the assessment of statewide model reasonability and validity though.

While initial statistics provided in this section can be used in assessing statewide model reasonableness and validity, the unique character of each state and model should be considered in comparing against any typical ranges documented herein. It would generally be better to compare statistics from newer statewide models against those of specific states (rather than general statewide model ranges) felt to be similar in terms of urbanization patterns, economy, and other sociodemographic characteristics. For statewide models largely dependent on trip-making in rural areas, it stands to reason that traffic assignment accuracy standards would be more lenient than typically expected for urban and regional travel demand models.

4.0 Modal Issues

The purpose of this section of the report is to summarize how modal issues have been addressed in developing and validating statewide models. The issue of which modes to include in statewide models continues to be debated in many states. Presence or lack of transit/rail networks and skims, mode choice models, and transit assignment processes are addressed in this section. Documentation of 25 statewide models included information discussing modal issues out of the 30 statewide models that were reviewed overall.

When a state is developing a statewide model, the complexity of policy issues to be addressed often determines the need for a mode choice step. More basic statewide models like Alabama are used to estimate intercity and rural passenger travel and do not require a mode choice step. However, a more complex model like the one for California High-Speed Rail, with existing intercity rail and plans for future high-speed rail, requires a mode choice step. One modal consideration for states is to decide if a mode choice step is required and if so, what kind of mode choice application would best accomplish the overall purpose of the statewide model. Simple models that estimate intercity and rural auto and/or truck travel demand may not require a mode choice step or may only need a basic auto occupancy application. However, states that choose to estimate travel demand for additional modes such as intercity transit and high-speed rail, require a more complex mode choice model.

Passenger trips in statewide models are typically divided into transit and highway modes, while freight trips can be allocated to truck, air, water, and rail modes. Passenger trips also can be divided among different toll and/or HOV user classes. Some statewide models include transit in a variety of forms, although these tend to be in areas of the country where intercity passenger rail plays a significant role in travel demand. When a state decides to incorporate transit modes into its statewide modeling system, it usually reflects significant existing transit travel demand and/or a need for modal outputs.

If a freight model is in place, truck estimates can be derived separately through a mode choice model that splits freight tonnages by mode and converts truck tonnages to vehicles. An additional process is needed to incorporate nonfreight trucks, which can be a substantial component of truck travel, particularly in MPO model areas. In addition to highway networks, rail networks also are used in a few statewide models, such as those for California, Ohio, and Wisconsin that estimate forms of passenger rail and/or freight rail, and the Delaware, Pennsylvania, Tennessee, and Texas models that include freight rail. Freight rail trip tables can be estimated using a mode choice model that separates trucks from rail based on mode targets provided by FAF, TRANSEARCH, and other sources. Assuming reasonable transit trip tables could be estimated through a mode choice process, these same freight rail networks could be used to model intercity passenger rail. Issues related to statewide freight modeling in general, and freight mode choice in particular, are discussed in Section 5.0. This section is focused more on mode choice for passenger trips.

Finally, another emerging modal stratification is to differentiate among users of toll facilities. For example, the travel behavior of vehicles with prepaid transponders differs from those paying tolls with cash. While toll simulation was once largely the domain of urban and regional models, studies of truck lanes and intercity toll roads have necessitated use of statewide models and corridor validation. Florida's Turnpike Statewide Model[13] forecasts toll facility travel demand along urban, rural, and intercity corridors. The following subsections describe modal differences between statewide and urban models, mode choice approaches used in statewide models, statewide mode choice validation, modes considered in statewide models, and mode splits documented for statewide models.

It also should be noted that budget and cost might impact the ability to incorporate additional modes into a statewide model. For example, the original version of the Rhode Island Statewide Model had a mode choice model and a fully coded bus system. However, when it was converted to a new software platform, the State did not have the money to convert the whole model. Since that time, the State identified the needed funding and a newer release of the model now has transit capabilities.

4.1 MODES SELECTED FOR ANALYSIS

The modal issues facing statewide models are different from those of traditional urban models because statewide models include large areas without access to transit. For example, most regional models focus on trips within and immediately external to urbanized areas. Meanwhile, statewide models include all urban and rural areas within an entire state along with potential bordering zones. Some statewide models extend throughout the entire U.S., Canada, and Mexico, primarily to model freight flows. Due to the size of coverage areas, modes such as local bus services are not typically included in statewide models. Also, due to the existence of urban models, most statewide models tend to focus on interregional and rural trips. Due to the scale of statewide models, some modes considered in urban models, such as nonmotorized, would not be practical in a statewide model. Transportation modes that represent, say, one percent of all trips in an urban model might represent only a fraction of a percent at the statewide level. Because of these issues, most statewide models tend to focus solely on auto and truck travel.

[13] Florida's Turnpike Enterprise *State Modeling Approach Methodology Report*, January 2007.

Since the focus of most statewide models is to model intercity and interregional trips, the models tend to only apply mode choice to auto and truck trip types. There are a few models that include other modes of travel. For example, the Wisconsin Statewide Model simulates intercity bus trips, but does not include urban/intraregional transit trips.

The California High-Speed Rail (HSR) model forecasts and assigns rail passenger trips for the purpose of planning for new intercity rail lines and the State's planned HSR system. The model combines statewide intercity trip tables with intraregional person trip tables from four urban/regional models and conducts a joint highway and transit assignment process, minimizing the duplication that often occurs between statewide and urban/regional models. The model also includes air trip tables based on Federal Aviation Administration (FAA) data. The California Statewide Model is quite complex and requires substantial time for model execution. Other statewide models that use MPO/urban model trip tables and other inputs include Ohio and Oregon. Each of these statewide models also have included transit as part of the modeled modes.

4.2 Mode Choice Approaches

Most statewide models have used the traditional four-step process; however, there are several statewide models that use differing elements of trip chaining. Of the 30 statewide models reviewed for the project, only 25 described transportation modes found in the model. Seven of the remaining 25 models examined for modal issues did not include a mode choice step (Alabama, Georgia, Kentucky, Louisiana, Mississippi, Rhode Island, Utah). Of these models, Alabama and Rhode Island were basic passenger models, both with freight models still under development at the time of documentation (Rhode Island very recently added mode choice to its Statewide Model). Georgia estimates both auto and truck travel, splitting truck trips into commodity-carrying and noncommodity-carrying components, but does not include a mode choice step. Louisiana, Mississippi, and Utah rely on a great deal of input data to determine auto and truck trips, but do not seem to include a mode choice step. New Mexico also planned to develop a mode choice model, but this component was never developed.

Generating modal shares is accomplished in various ways in statewide models. Two common approaches are logit-based choice models, and fixed share allocations. The choice model or nested logit model assigns a hierarchy to the modes to account for multiple decisions made when a passenger selects a mode. Like or competing modes are nested together to account for the level of competiveness when individuals are choosing a mode. The Ohio and Oregon statewide models use microsimulation approaches to predict travel behavior for each of the modes, including auto, bus, and truck. The Oregon Statewide Model uses a nested logit mode choice model to break down trips by public or private and further by auto occupancy and type of transit. Nested logit methods also are used by Delaware, Indiana (long-distance trips), and Texas. Delaware heavily relies on tolling data to determine auto occupancy and allocate passenger trips into cash toll, prepaid transponder, or nontoll users. Indiana (short-distance trips), Virginia, and Wisconsin are among the states that use fixed share mode choice models.

Fixed share models assume a fixed ratio of trips allocated to each mode and do not fully account for changes in mode share due to changes in relative level of service among modes. The Wisconsin Statewide Model uses destination choice step to estimate the origin and destination of each long-distance trip and determine the level of intercity travel. Then a fixed share mode choice step is applied to all long-distance trips where passengers have the choice of making intercity trips by auto, intercity bus service, or intercity rail service. This method works for the Wisconsin model because the State experiences a larger number of recurring and nonrecurring intercity trips between Madison, Milwaukee, Chicago, and other surrounding markets.

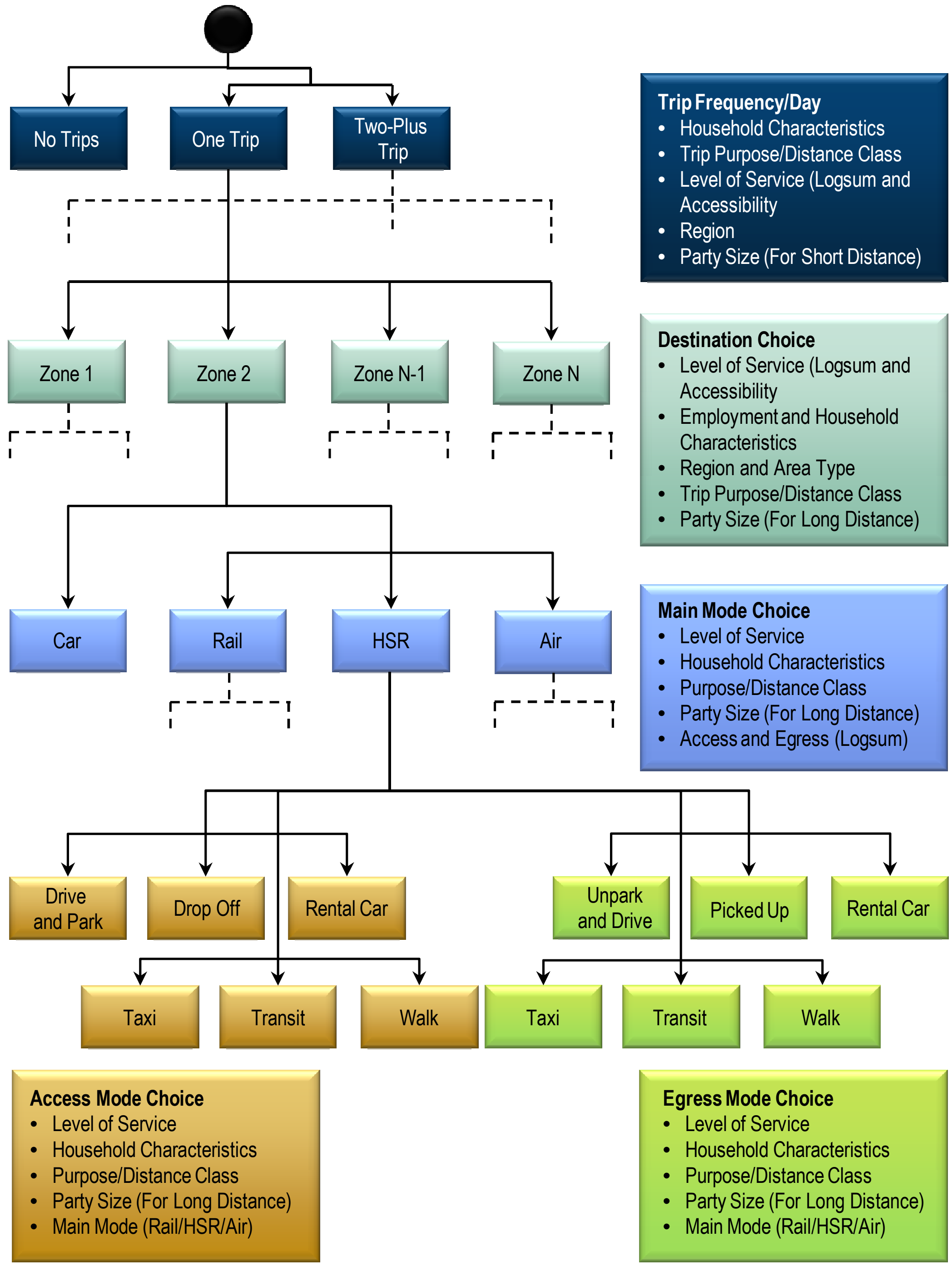
While traditional statewide models estimate auto and truck trips only, there has been a push towards including more modes, including different types of transit and freight modes. While including multiple modes increases the model's complexity, such decisions are largely based on current ridership levels in conjunction with competing modes, and plans for modal expansions. As noted previously, the California Statewide Model includes auto, air, and intercity rail, all of which are competing modes to the planned HSR. The statewide model also includes modal split inputs from four regional models, which include substantial local transit systems, with bus, light rail transit (LRT), heavy urban rail, commuter rail, and streetcars. Figure 4.1 depicts the California HSR model structure, including the access and egress modes.

4.3 Mode Choice Validation

The Florida and Wisconsin statewide models compare model estimates with National Household Travel Survey (NHTS) data for the purposes of validation. The California Statewide Model used the American Travel Survey (ATS), Census Transportation Planning Package (CTPP), and The California Statewide Travel Survey to validate interregional trips. These sources are examples of commonly used validation data for establishing mode choice targets. The validation process also can be performed at different geographic levels.

Of the 18 models (out of the 25 that discussed modal issues) reviewed that included a mode choice step, few included documentation on mode choice validation. Many of the models reviewed were validated only using outputs from the traffic assignment step. This can lead to serious errors with a model, by not uncovering and correcting errors that occur in some of the earlier steps of the model.

Figure 4.1 California Statewide High-Speed Rail Model
Access and Egress Modes



Source: Cambridge Systematics, Inc.

4.4 MODES CONSIDERED IN STATEWIDE MODELS

Of the 25 statewide models reviewed for this section of the report, about half considered modes other than auto and truck. Of these states, 9 included rail, 6 included air, 4 included some form of bus, and 3 included waterborne transportation. Most statewide models include rail as a freight mode only. Intercity passenger rail was estimated in California, Ohio, and Wisconsin, and California additionally separated intercity rail from high-speed passenger rail. Delaware, Ohio, and Oregon included bus modes within urban areas, while both Ohio and Wisconsin included intercity bus and rail travel. Only 4 of the 14 statewide freight models included nesting of truck modes. Florida, New Jersey, and Oregon based their truck modes on the truck size categories, while Georgia used commodity-carrying and noncommodity-carrying truck modes.

Table 4.1 provides a summary of transportation modes simulated in statewide models throughout the U.S. The modes chosen by states for their statewide models show that states tend to model those modes that are of importance to the state as a whole. Additional information is provided on trucks in Section 5.0.

Table 4.1 Modes Simulated by State

Modes	CA	DE	FL	GA	IN	IW	LA	MA	MS	NJ	NM	OH	OR	PA	RI	TX	VA	WI
Auto	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Air	●		●									●				●	●	●
Bus (Generic)		●											●					
Intercity Bus												●						●
Rail (Generic)	●	●	●								●	●		●		●	●	●
High-Speed Rail	●																	
Intercity Rail																		●
Amtrak												●						
Truck			●	●	●	●	●	●	●	●	●	●				●	●	●
Light-Truck			●							●			●					
Medium-Truck			●							●								
Heavy-Truck			●							●			●					
102-Inch Truck										●								
Container Truck													●					
Commodity-Carrying				●														
Noncommodity-Carrying				●														
Commercial Vehicle								●										
Water												●					●	●
Intermodal				●														

4.5 MODE SPLIT REASONABLENESS COMPARISONS

Mode splits (or auto occupancy rates) are typically summarized in urban and regional travel demand model documentation. However, since modes other than auto often account for a small percentage of trips at the state and intercity level, mode splits are not reported for the majority of statewide models. As depicted in Tables 4.2 and 4.3, of the 25 statewide model documents reviewed for modal issues, only three reported their mode split percentages (freight and/or passenger) and/or auto occupancies. These states were California, Florida, and Ohio. In California and Ohio, auto trips comprised the majority passenger mode spilt with 95.7 percent in California and 92.7 percent in Ohio. Passenger air, a mode unique to statewide and multistate models, was second with 3.7 percent (California) and 5.3 percent (Ohio). Rail accounted for the rest of the passenger trips in California and bus comprised the remainder for Ohio. In both of these cases commercial truck/freight trips were appropriately excluded from passenger modal splits.

Table 4.2 Modal Split by State

Mode	California	Ohio
Auto	95.7%	92.7%
Air	3.7%	5.3%
Urban Bus	–	0.2%
Greyhound Bus	–	0.2%
Rail	0.6%	–
Amtrak	–	0.1%
Other	–	1.5%
TOTAL	**100.0%**	**100.0%**

Table 4.3 Freight Modal Split by State

Mode	Florida	Ohio
Air	0.0%	0.3%
Rail	11.0%	6.9%
Truck	83.0%	92.2%
Water	1.0%	0.6%
Intermodal	5.0%	–
TOTAL	**100.0%**	**100.0%**

Both the Florida and Ohio statewide model documents reported freight model mode splits separately from passenger mode splits. The mode splits are consistent between the two models, with trucks receiving a majority of the trips, followed by rail and then water and air. The Florida Statewide Model includes a mode choice model for freight but only applies auto occupancy factors to convert passenger person trips to vehicle (auto) trips. Due to the limited amount of reported data on mode splits for statewide models, it is difficult to quantify an appropriate range of mode splits based on review of existing documents. States participating in the recent 2009 NHTS Add-On survey may be best equipped to estimate target mode splits by trip purpose for interurban travelers, although the older 1995 American Travel Survey (ATS) has a more robust sample of long-distance travelers.

4.6 FUTURE DIRECTIONS

In reviewing modal issues facing statewide models, the documentation shows that while states have a variety of methods to deal with modal choices, each state bases its method on the planning analysis needs for which its model was developed. California's model focuses on interregional and intraregional air, high-speed rail, and commuter rail. The Wisconsin Statewide Model estimates long-distance intercity travel by auto, bus, and rail. The Virginia Statewide Model has the capability of modeling high-speed rail, air, and long-distance bus but does not include these modes because they currently are not needed for the State's planning purposes.

Most of the statewide models reviewed focused on auto and truck trips, leaving detailed intra-urban transportation modes for analysis with urban models. Therefore, when a state is considering how to address mode choice in a statewide model, consideration is given to potential uses of the model, and the anticipated uses and study types for which the model will be applied.

In recent years, Congress has passed legislation allocating funds for the development of high-speed rail (HSR) corridors in multiple states throughout the U.S. Despite the Federal government's recent focus on HSR, few states have models that are capable of modeling or validating that mode. Of course, many states do not need to model HSR despite the Federal initiative, and others have used analytical tools other than statewide models (e.g., "superregional" models that combine more than one preexisting urban/regional model) to analyze high-speed rail. The new focus on HSR is becoming an incentive, in the case of Florida as an example, to add multimodal capabilities to their statewide model, now that funding has been provided for HSR implementation.

In recognition of multi-urban area/multistate/multimodal modeling for high-speed rail corridors and mega-regions, FHWA has initiated the American Long-Distance Personal Travel Data and Modeling Program. This new program looks to update the 1995 American Travel Survey (ATS), perhaps on a more regular basis, and begin the process of developing a national passenger demand model with multimodal modeling capabilities. In the meantime, model developers can rely on the ATS database in order to document additional mode choice benchmarks for use in statewide models, such as the percentages by mode and trip purpose depicted in Table 4.4. Additionally, the 2009 NHTS, which included many state Add-On surveys, might provide a sufficient sample of long-distance travelers nationally to check against findings from the 1995 ATS.

Table 4.4 Percent of Person Trips by Means of Transportation and Trip Purpose

		Main Purpose of Trip				
			Pleasure			
Principal Means of Transportation	Total[a]	Business	Total	Visit Friends or Relatives	Leisure	Personal Business
Number (Thousands)						
All Person Trips[b]	1,001,319	224,835	630,110	330,755	299,355	146,338
Personal use Vehicle	813,858	151,697	537,339	283,153	254,136	124,791
Commercial Airplane	155,936	67,083	73,462	41,881	31,581	15,386
Intercity Bus	3,244	286	2,519	1,830	690	439
Charter or Tour Bus	14,247	1,281	10,451	1,198	9,253	2,514
Train	4,994	1,342	2,948	2,004	944	704
Ship, Boat, or Ferry	614	68	525	43	483	20
Percent						
All Person Trips[b]	100.0	22.5	62.9	33.0	29.9	14.6
Personal use Vehicle	100.0	18.6	66.0	34.8	31.2	15.3
Commercial Airplane	100.0	43.0	47.1	26.9	20.3	9.9
Intercity Bus	100.0	8.8	77.7	56.4	21.3	13.5
Charter or Tour Bus	100.0	9.0	73.4	8.4	64.9	17.6
Train	100.0	26.9	59.0	40.1	18.9	14.1
Ship, Boat, or Ferry	100.0	11.1	85.5	7.0	78.7	3.3

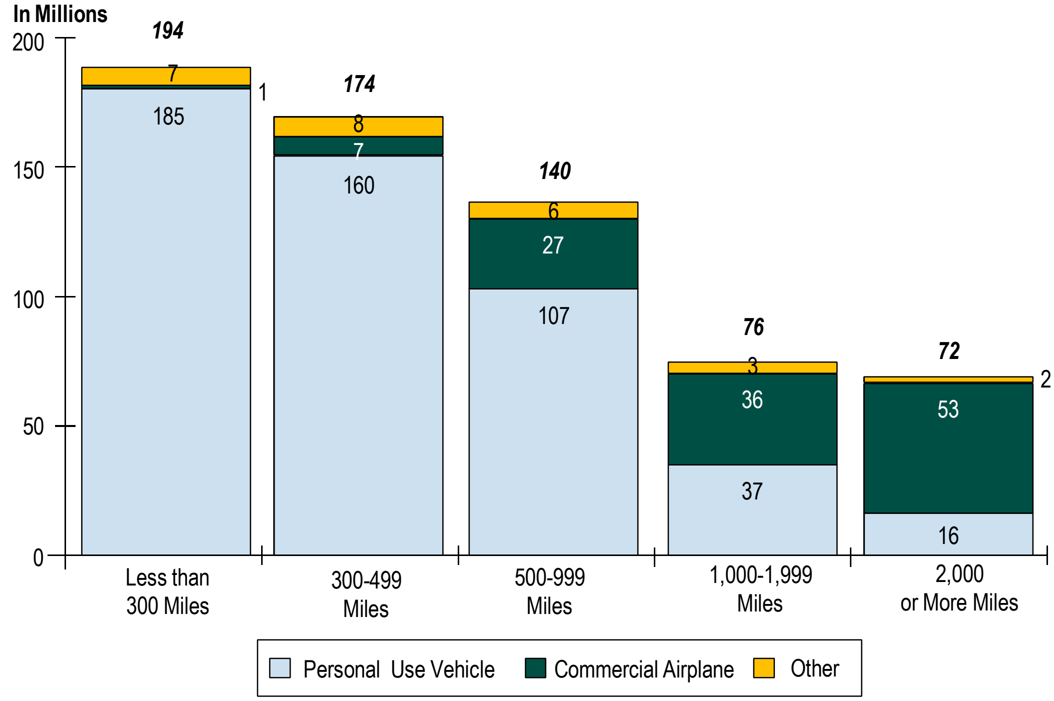
Source: U.S. DOT Bureau of Transportation Statistics. *1995 American Travel Survey Profile. United States.* October 1997. Trips of 100 miles or more.

[a] Includes other purposes not shown separately.

[b] Includes other means of transportation not shown separately.

Figure 4.2 depicts additional mode choice statistics from the ATS, stratified by trip length, that might be useful in evaluating mode choice for statewide models, multistate models, and an eventual national model, understanding that available transportation modes and resulting mode splits vary significantly by state.

Figure 4.2 Percent of Person Trips by Means of Transportation and Trip Length



Source: U.S. Department of Transportation Bureau of Transportation Statistics. *1995 American Travel Survey Profile. United States*. October 1997. Trips of 100 miles or more.

Note: Numbers and percents may not add to totals due to rounding.

5.0 Statewide Freight Models

Statewide freight models are used to provide policy information on freight demand and performance. The models may be used to provide demand and performance information which cannot be obtained from simple observations in the current year, or to provide forecasts of freight demand and performance for a future year. In the current year it may be desirable to determine the volumes of truck flows on a facility by the commodities carried, which is information that cannot be determined by unobtrusive observation of trucks. In a forecast year, it may be desirable to know the volume and performance of freight on existing and planned facilities, in order to evaluate the costs and benefits of plans, programs, and projects. In order to properly validate statewide freight models, it is important to understand how these models function.

5.1 Classes of Statewide Freight Models

This subsection explores several approaches to freight models that have been implemented in statewide models. Each of these approaches differs with respect to data requirements, level of output detail, and validation data requirements. The selection of a suitable freight modeling approach depends on the kind of policy needs the statewide model is intended to address. These approaches have typically been applied as follows:

- **No Freight Model –** Modeling may be restricted to MPOs within the state and the state DOT does not operate a model which covers all of the MPOs in the state as well as the rural areas between MPOs; or the state DOT may operate a model, but that model covers only passenger trips or includes total highway vehicles, and does not separately report demand or performance for vehicles which carry passengers and those which carry goods.
- **Truck Model –** The state DOT operates a travel demand model and that model separately forecasts the demand and performance of autos and trucks on the highway network, but does not distinguish between trucks which carry freight and trucks which provide other functions (e.g., service, maintenance, construction, local delivery). Also, the travel demand model does not include forecasts for nonhighway freight modes.
- **Direct Commodity Table Freight Model –** The state DOT operates a travel demand model, and that model, rather than including modules which calculate a trip table for freight vehicles, processes a directly acquired multimodal commodity table into a freight truck trip table. That table is assigned to a highway network, either separately or most often as part of a multiclass assignment with autos and other trucks.

- **Four-Step Freight Model –** The state DOT operates a travel demand model and that model forecasts a freight truck trip table, in addition to trip tables for other nonhighway modes, through the use of trip generation, trip distribution, and mode choice modules. Freight truck trips are then assigned to the highway network, either separately or most often as part of a multiclass assignment with autos and other trucks.
- **Economic Freight Model –** The state DOT operates a travel demand model which calculates the demand and consumption of freight as a result of activities modeled in an economic model. The difference from the Four-Step Freight Model above is that the employment or other indicators of economic activity which generate the production or consumption of freight are not provided exogenously, but are calculated iteratively within the model as a result of its calculations of transport costs.

Table 5.1 classifies existing statewide freight models into the above categories. The classification includes only operational models used in forecasting, not models which are primarily for research purposes. For example, Texas is classified based on the Texas Statewide Analysis Model (SAM), not RUMBRIO, a random utility-based multiregional input-output, transportation land use model as described in Subsection 6.2, which is a research project that has not yet been incorporated into operational planning.

Other classifications were considered but were not used. The Oregon Freight Model, which is listed in Table 5.1 as an economic model, is a hybrid micro-simulation model which attempts to link commodity flow movements from an economic model into vehicle tours that pass through intermediate distribution and warehousing facilities. Only two state Economic Freight Models are shown in Table 5.1, the Oregon Model, and the draft Ohio Freight Model. While the calculation of the freight flows from the economic value shipped between zones is a distinguishing feature, rather than overgeneralizing from insufficient data, it also might be appropriate to consider these models as Four-Step Freight Models with an integrated economic model, and thus an extension of the Four-Step Model, rather than an entirely separate category.

The next subsection describes validation issues for statewide freight models. This is followed by subsections describing noteworthy features of statewide freight models by the model classifications used in Table 5.1. There is no discussion of states which lack any form of freight model, most of which also have no statewide passenger models. The section concludes with a discussion of data sources for freight model validation and sensitivity analysis.

Table 5.1 Statewide Freight Models

State Name	No Freight Model	Truck Model	Direct Commodity Table Model	Four-Step Freight Model	Economic Model
Alabama		●			
Alaska	●				
Arizona		●			
Arkansas	●				
California	●[b]				
Colorado	●[a]				
Connecticut		●			
Delaware		●			
Florida				●	
Georgia			●		
Hawaii	●				
Idaho	●[a]				
Illinois	●[a]				
Indiana				●	
Iowa		●			
Kansas	●[a]				
Kentucky			●		
Louisiana			●		
Maine		●			
Maryland		●			
Massachusetts		●			
Michigan				●	
Minnesota	●				
Mississippi			●		
Missouri		●			
Montana			●		
Nebraska		●			
Nevada	●				
New Hampshire		●			
New Jersey		●			
New Mexico			●		

State Name	No Freight Model	Truck Model	Direct Commodity Table Model	Four-Step Freight Model	Economic Model
New York	●				
North Carolina	●				
North Dakota	●				
Ohio				●	
Oklahoma	●				
Oregon					●[c]
Pennsylvania				●[c]	
Rhode Island		●			
South Carolina	●[a]				
South Dakota	●				
Tennessee			●		
Texas				●	
Utah		●			
Vermont		●			
Virginia			●		
Washington	●				
West Virginia	●				
Wisconsin				●	
Wyoming	●				

[a] No information obtained.

[b] Travel Demand Model does not report truck volumes or performance.

[c] Includes the estimation of trips through intermediate distribution and warehouse centers.

5.2 Freight Model Validation

The models discussed will forecast freight flows on highway networks, but in a form which is combined with other nonfreight movements. The exception is Truck Models where the truck counts used in validation should be able to match the modeled data. In all other freight models, the validation data will include trucks which do other things besides carrying freight. Therefore validation of freight truck volumes will have to be largely subjective, with one exception.

Since truck counts will include nonfreight trucks, in no instances should freight truck volumes exceed total truck counts. Otherwise, the freight truck volumes can only be examined to see that these appear to be a reasonable percentage of total trucks, and a reasonable percentage will vary by facility and location with a region. If validation screenlines are to be established for freight trucks, these should be on links in fairly rural areas on major facilities. On these rural facilities, the majority of trucks can be considered to be freight trucks.

Because the commodity flow survey may be used directly (as in Direct Commodity Table Freight Models) or be the basis for developing model equations and parameters (as in Four-Step Freight Models), that same survey should not also be used to validate the model. If available, commodity flows survey for a prior year could be used to validate the ability of the model to "backcast" freight flows, assuming prior year employment, networks, and other explanatory variable also are available.

Caution must be exercised in using the same dataset for both calibration data and validation data. Therefore, unless a commodity flow database is available which is different from the one which was used to calibrate the model, it may not be possible to validate the trip generation, trip distribution, and mode choice steps. In the event that an independent commodity flow database is available, differences in commodity definitions or geography may make it impossible to determine if differences are due to the model coefficients and parameters or the factors used to make the geography, commodity classification, or coverage of the dataset which is being considered for use in validation equivalent to that used in the model. While it may be tempting to validate the results with those of other statewide models with similar characteristics such as trip generation, trip length, or mode split, the geographic and economic setting of each state is so different that this is not advisable. All that may be possible is to apply "reasonableness" checks such as whether or not the average trip lengths, mode shares, and tons per employee are consistent with those presented in documents such as the QRFM2.

5.3 Truck Models

Goal: The ability to forecast total truck performance, without distinguishing freight trucks from nonfreight trucks.

Truck models are similar in format to urban travel demand models. In small dense urban states, including Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, and New Jersey, where there might be many MPO travel demand models in close proximity with smaller sections in rural areas, or in the case of Rhode Island where the MPO includes the entire State, the development of a Truck Model can be seen as a natural extension of MPO travel demand modeling. In other states, including Alabama, Arizona, Iowa, Maine, Missouri, Nebraska, Utah, and Vermont, the model includes substantial sections of rural highways between MPO travel demand models. In these states the Truck Model is used to provide forecasts of truck travel to, from, and through MPOs at their external stations by forecasting travel between zones which are included in MPOs, and to forecast truck volumes and performance on the rural highways between MPO travel models.

These models do not distinguish between long-haul freight trucks and shorter-distance local delivery freight. Since there is no need to assign long-haul traffic to a long-haul network or zone structure, the geographic coverage of these models are typically the subject state, and optionally a buffer of surrounding zones in neighboring states. At the boundary of the model there are external stations where trucks enter and exit the model network.

Truck models are typically an extension of urban travel demand models and typically include not only trucks but autos, and calculate the routing and performance of trucks simultaneously with autos.

While it is possible to use preloading or other assignment techniques for trucks, this is not typically used in statewide Truck Models. The different responses of trucks in assignment are based on knowledge of truck purpose and/or distance traveled beyond the model boundaries, neither of which is typically identified in these models.

By including only trucks, the ability to model the demand, performance, or shift to and from nonhighway freight modes cannot be explicitly included in the model. However, off-model modifications of the truck trip tables may be used to simulate policy alternatives using other modes and the impact on volumes and performance tested by assigning the modified truck trip tables.

The explicit identification of intermediate distribution and warehousing centers as part of a long-distance trip is not included because long-distance truck trips, especially the portion of the trip outside of the model boundaries, are not separately identified in the model.

The commodities being transported by freight trucks on the network cannot be determined in simple Truck Models. Accepting the premise that facilities with high truck volumes are those which also are important freight routes, the facility performance can be identified and used in lieu of specific freight performance.

Ideally, the trip generation rates and friction factors used in trip distribution are developed from a commercial vehicle (truck) survey specifically conducted for the Truck Model. While this is sometimes the case (e.g., New Jersey's Statewide Model[14]), more often the rates for the MPOs within the state, or rates borrowed from other models, are used in the statewide Truck Model. If rates and parameters (such as average trip length, friction factors) are not specifically developed for the area served by the statewide model, these values should be revisited during model validation.

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[14] URS Greiner Woodward Clyde, *Statewide Model Truck Trip Table Update Project*, prepared for the New Jersey Department of Transportation, January 1999.

Validation

The use of new and existing truck classification counts should be considered in model validation. The traffic counts in some MPOs are used in more than just standard validation of screenlines. In Atlanta, Washington, Baltimore, and several cities in Ohio, the truck trip tables themselves are adjusted through a process called Adaptable Assignment.[15,16,17] For the Alameda County Congestion Management Agency truck model,[18] a matrix estimation process was used to develop a synthetic truck trip table from observed counts, and the resulting trip table was used in lieu of a survey to calibrate the model. While neither procedure has been used in statewide Truck Models, there is no technical reason that this process could not be used.

While it is true that all counts need to be properly processed for use in the validation of any forecasting model, it is important to remember how truck counts should be processed for use in validating freight models. When truck classification counts are used, care should be taken to ensure that unadjusted raw counts are not used. Also, Annualized Average Daily Traffic volumes, which reflect conditions averaged over the entire week, including weekend and holidays, may not reflect the conditions forecast in the model. If the model is to reflect average midweek conditions for a specific base year, the truck classification counts should be adjusted to midweek volumes for that same year before they are used in validation. Data from permanent classification stations, weigh-in-motion (WIM) stations and other information generally available from state DOTs, FHWA, and AASHTO can assist in developing these weekday truck adjustment factors.

The statewide Truck Models which were examined typically included categories of trucks based on size, heavy, and medium trucks. However, during the calculations in Trip Generation and Distribution, additional classifications are often made based on land use purpose. If these classifications were maintained during the Truck Trip Generation and Distribution process and separate trip tables were created using these classifications, it would be possible to assign these disaggregated truck tables as part of a multiclass assignment and report on the performance and volumes of these separate classifications of trucks.

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[15] Allen, William, Jr., *Adaptable Assignment*. http://ntl.bts.gov/lib/7000/7400/7498/789768.pdf.

[16] Bandy, Gene, *An Innovative Approach to Truck Modeling: Baltimore Region Application, Presentation at the 2004 AMPO Annual Conference. San Antonio, Texas, October 14, 2004.*

[17] Atlanta Regional Commission, *The Travel Forecasting Model Set For the Atlanta Region: 2008 Documentation,* Atlanta Regional Commission, Updated November 2008.

[18] Cambridge Systematics, *Draft Final Report: The Countywide Travel Demand Model Update to Improve Modeling Truck Impacts*, Alameda County Congestion Management Agency, January 2010.

Care should be taken in validating truck model components using commercial vehicle/truck surveys which may have been used to estimate those same model components. However, if previous commercial vehicle/truck surveys are available, the trip generation rates which can be developed from these prior surveys can be used to validate those rates in the Truck Model. Similarly the trip length frequency distributions or average trip lengths in prior surveys can be compared to those in the model forecasts, in order to validate the trip distribution modules. If other truck intercept surveys are available, and were not used in model calibration, the origins, destinations or truck purposes from these intercept surveys can be used to validate the trip distribution module.

5.4 DIRECT COMMODITY TABLE MODEL

Goal: The ability to incorporate directly acquired forecasts of commodity flow into the forecast of freight truck demand and performance and possibly the commodity flow of other nonhighway freight modes.

The estimation of network volumes and performance requires a trip table and an assignment procedure. While traditionally a freight truck trip table might have been developed synthetically through trip generation, trip distribution, and if necessary mode split, it is possible to use a direct survey of commodity flows in place of a synthetically generated trip table. Many statewide freight models have been developed using the assumption that an annual commodity flow survey of the appropriate geographic coverage can be transformed into a daily truck trip table, and that this survey-based trip table can be used in place of a synthetic trip table. Since a commodity flow survey has typically already been statistically expanded to annual flows, it is merely necessary to apply a factor to convert this to daily flows. The Quick Response Freight Manual II (QRFM2)[19] suggests that a factor of 306 working days per year be used, although other local factors might be considered. If the table is converted, then it may be necessary to convert the geography of the survey zones into the traffic analysis zones associated with the freight model.

The publicly available commodity surveys which include trucks, the Commodity Flow Survey (CFS) and the Freight Analysis Framework2 (FAF^2), have large geographic zones, less than 200 zones for the entire United States, and this geography is not consistent with the units of geography used in statewide freight models. The fine structure required of statewide freight models, typically includes zones within the state that are counties or disaggregations of counties. To meet the requirements of statewide models, either the publicly available commodity flow databases would have to be disaggregated, or databases from commercial vendors which are more disaggregated would have to be obtained.

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[19] Cambridge Systematics, *Quick Response Freight Manual II,* FHWA, Publication No. FHWA-HOP-08-010, September 2007.

All of the statewide freight models cited as being Direct Commodity Table Freight Models were developed using the commercial TRANSEARCH commodity flow database. In fact, the Virginia Statewide Freight Model[20] refers to commodity freight truck trip tables as "Reebie" trucks, which is based on the name Reebie Associates, which was the vendor of TRANSEARCH at the time the Virginia Statewide Model was developed. TRANSEARCH is now a product of Global Insight.

If the statewide freight model uses zones smaller than counties, then the commodity flows must be disaggregated further. The state may choose to disaggregate the data in-house, although it then needs to develop the data necessary for disaggregation, which should include detailed employment data for the industries producing and consuming each commodity reported in the freight database. Alternatively, finer geographies may be available from the vendor for an additional fee. In the case of the Virginia, Mississippi, and Louisiana Direct Commodity Table Freight Models, freight trucks, in addition to long-distance auto traffic, is suballocated to micro zones from the macro (county) zones which are consistent with the TRANSEARCH geography using network distance and zonal data.

The zone structure outside of the state is largely dictated by the zone structure outside of the state in the commodity flow database. Typically these are large zones and will represent nearby counties, BEA EA (Bureau of Economic Analysis Economic Areas) zones, states, and/or major U.S. Census regions.

If truck traffic will be assigned from these external zones it will be necessary to determine the external station which is used to enter the area served by the detailed statewide model. This may require a skeletal network connecting the external zones outside of the state. This network is typically sparsely detailed. If only freight truck traffic is loaded on the network outside of the state, the travel times and paths outside of the state are only a general representation and are only used to provide a connection with the detailed network within the state, and should not be used as an indication of performance on these external roadways.

Since the intent is only to allocate freight traffic from outside the state to the external stations of the model, it also is possible to associate external zones outside of the state with external stations at the state model boundary, and to preprocess the table to convert the external zones to these external stations. This process is identical to the subarea network extraction[21] of large networks and

[20] Wilbur Smith and Associates, *Virginia Multimodal Statewide Transportation Model Methodology Report,* Virginia Department of Transportation-Transportation Mobility Planning Division, Revised January 28, 2005.

[21] Extracting a subarea model from a larger (typically regional) model involves defining the spatial extent of the subarea, and extracting a subarea network and the corresponding subarea trip table. The external network and travel data is removed, with the resulting model serving essentially as a window on the regional model.

zones to subarea boundaries formed by the statewide model. Either computer programs in transportation modeling packages that conduct subarea windowing can be used, or a manual process accomplishing the same result can be followed. For example, the Georgia Statewide Freight Model windowed the TRANSEARCH truck table to the external stations at the boundary of the statewide model.

Commodity Flow Surveys will include separately reported tonnage flows using a commodity classification system. TRANSEARCH, which is cited as used by all of the statewide models in this category, uses the Standard Commodity Classification (STCC) System. The STCC is a hierarchical system and TRANSEARCH reports at two- to four-digit levels of increasing detail. This detail is beyond the requirements and data management capabilities of statewide freight models, and typically no more than a two-digit STCC code is used in developing tables. While some states combine the tables which can be produced by each STCC2 code, maintaining the ability to assign tables and report flows by STCC is a desirable analysis feature.

In addition to converting from annual flows to weekday flows as discussed above, it is necessary to convert from tonnage units to truck units before doing a multiclass assignment with other vehicle trip tables. This is accomplished through the use of tables to convert from tons to trucks. The factors of tons per trucks are typically considered to vary by commodity, which is an additional reason for maintaining separate commodity tables. These payload factors can be developed from a number of sources. These payload factors may consider full and empty miles, may have different values for different distance ranges, or may include different factors by the type of movement. The QRFM2 includes a table of payload factors from the Virginia model which is by commodity and movement type. These payload factors may be included in the TRANSEARCH commodity flow database, may be borrowed from other states, may be developed from records for a state from the Vehicle Inventory and Usage Survey (VIUS), FAF, or from other direct surveys. The Virginia truck load factors are depicted in Table 5.2. It should be noted that there is considerable variance in reports of payloads from surveys of driver or truck owner compared to that which is observed in WIM surveys. These variances are large, even when the sample sizes are large. Thus, the variability is probably inherent rather than sampling error and it should be recognized that the inability to precisely state the payload factors will impact the ability to validate freight models.

Direct Commodity Table Freight Models include not only the flows between origins and destinations by commodity, but also an indication of the mode which is used to carry that freight. The TRANSEARCH commodity flow database which was used by all of the statewide models cited in this category, includes four freight modes: 1) three truck submodes, based on the characteristics of the truck operator: Full Truckload, Less Than Truckload, Private (truck owned by shipper or receiver); 2) two rail submodes: carload and intermodal; 3) domestic water; and 4) domestic air cargo. Direct Commodity Table Freight Models have a predetermined mode share, but this mode share may be varied by simple ad-hoc off-model changes to the trip table to test policy alternatives.

Table 5.2 Virginia Freight Model Truck Load Factors
Tons per Truck

STCC	Commodity Type	Movement Type		
		Intrastate	Interstate	Through
01	Farm Products	16.1	16.1	16.1
09	Fresh Fish or Marine Products	12.6	12.6	12.6
10	Metallic Ores	11.5	11.5	11.5
11	Coals	16.1	16.1	16.1
14	Nonmetallic Ores	16.1	16.1	16.1
19	Ordinance or Accessories	3.1	3.1	3.1
20	Food Products	17.9	17.9	17.9
21	Tobacco Products	9.7	16.4	16.8
22	Textile Mill Products	15.2	16.1	16.5
23	Apparel or Relented Products	12.4	12.4	12.5
24	Lumber or Wood Products	21.1	21.0	21.1
25	Furniture or Fixtures	11.3	11.3	11.4
26	Pulp, Paper, Allied Products	18.6	18.5	18.6
27	Printed Matter	13.8	13.6	13.9
28	Chemicals or Allied Products	16.9	16.9	16.9
29	Petroleum or Coal Products	21.6	21.6	21.6
30	Rubber or Miscellaneous Plastics	9.1	9.2	9.3
31	Leather or Leather Products	10.8	11.0	11.3
32	Clay, Concrete, Glass, or Stone	14.4	14.3	14.4
33	Primary Metal Products	19.9	19.9	2.00
34	Fabricated Metal Products	14.3	14.3	14.3
35	Machinery	10.8	10.8	10.9
36	Electrical Equipment	12.7	12.8	12.9
37	Transportation Equipment	11.3	11.3	11.3
38	Instruments, Photo Equipment, Optical Equipment	9.4	9.4	9.7
39	Miscellaneous Manufacturing Products	14.2	14.4	14.8
40	Waste or Scrap Metals	16.0	16.0	16.0
50	Secondary Traffic	16.1	16.1	16.1

For truck assignments, the issues are no different than those discussed above for Truck Models, for the portion of the model within the statewide model areas. Any skeletal highway network outside of the primary model area might be included within the model.

While Direct Commodity Table Freight Models produce nonhighway modal trip tables, these trip tables may be only a means to the end of producing truck tables. However, if modal networks are available for these modes, an assignment procedure appropriate to that modal network may be used. For example, the Tennessee and the Virginia freight statewide models in this category include rail networks and assign the table of annual rail tons to a national rail network using an all-or-nothing assignment of minimum distance impedances. Nonhighway freight assignments are typically used only for very general policy analysis because the available information about the networks and the actual decision of the carriers to route traffic is more complex than a simple distance-based rule.

Future-year commodity flows may be acquired along with the base-year commodity flow survey. If acquired, then processing of the ton-flows for use in the freight model is similar to that of the base year. In this case, the overall flows between origins and destinations by commodity may change, but the existing mode share is assumed to remain the same. If a forecast of commodity flows was not obtained, then many statewide models apply growth factors of productions and attractions related to the economy of the zones, using an Iterative Proportional Fitting process, most often a FRATAR process. After forecasting future total, the existing mode share, or ad-hoc changes to that mode share, is applied to develop the modal flow tables. At this point the processing is identical to that used in the base year.

Validation

Validation issues concerning the use of truck counts discussed previously for Truck Model validation also apply for the Direct Commodity Table Freight models. An additional complication is that while traffic counts include all trucks, the freight trucks derived from a Direct Commodity Table Freight Model are only a subset of all trucks. In all cases the assigned freight truck volumes should be less than the total truck counts, but without additional information, it may not be possible to separately validate commodity truck volumes against truck counts.

If a network assignment of truck volumes can be obtained for a commodity flow database which was not directly included, it may be possible to check for consistency between the assigned flows from the Direct Commodity Table Freight Model and the alternative flows from that other commodity flow database. For example when the Direct Commodity Table Freight Model is developed from a TRANSEARCH database, it may be possible to compare the assigned freight truck volumes from this model with those assigned using the FAF2 databases. This does stop short of validation unless the assignment of truck flows in the other commodity flow database has itself been validated.

The commodity flow database may include trip tables of annual flows which have been developed from tonnage flows using tons to truck payload factors. If this is the case, the payload factors used in the Direct Commodity Table Freight Model can be compared with other independent sources of payload factors, for example VIUS.

5.5 Four-Step Freight Model

Goal: The ability to forecast the multimodal flow of freight from explanatory variables and to use those multimodal forecasts to develop forecasts of freight trucks, and possibly other nonhighway modes.

The process of disaggregating commodity flow survey zones from counties to the smaller traffic analysis zones in freight models requires the development of allocation factors. When the zone structure in the statewide model is sufficiently small enough, the equations which are necessary to use in disaggregating the survey flows will be virtually identical to the equations used in trip generations. The survey used in developing trip generation equations may be publicly available commodity flow surveys (Indiana's model[22] was developed from the Commodity Flow Survey) or may be a commercially available table (e.g., TRANSEARCH as used by all other statewide models in this category). Additionally, the statewide model may be used to test policy changes on productivity, employment, or population growth that would be different from those in a commercially purchased survey. In these cases, the commodity flow survey is used as the survey database from which to develop and calibrate the trip generation, trip distribution, and mode choice steps that are used to develop the trip tables used in the assignment step of a four-step model.

The previously mentioned Direct Commodity Table Freight Models will include in excess of 40 commodities, depending on the commodity classification system used in the survey. These commodities can be considered analogous to purposes in a passenger model in that it is assumed that the commodities have similar generation, distribution, and mode choice behavior. Maintaining over 40 equations in the model creates data management and resource issues. In Four-Step Freight Models, it is customary to combine commodities into approximately a dozen commodity groups retaining most important commodities for that state and combining other less important commodities. Table 5.3 provides an example of commodity groups found in the Four-Step Freight Model for Pennsylvania.[23]

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[22] W.R. Black, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment, Phase* 2, Bloomington, Indiana: Transportation Research Center, Indiana University, 1997.

[23] Mark Radovic and Larry M. King, *Validation of Pennsylvania Statewide Travel Demand Model*, paper presented at the 86th Annual Meeting of the Transportation Research Board, January 2007.

Table 5.3 Pennsylvania Statewide Freight Model Commodity Groups

1	Unprocessed Agricultural/Fishing Products
2	Unprocessed Ores and Petroleum
3	Coal
4	Processed Food and Tobacco
5	Textiles and Apparel
6	Lumber and Wood Products
7	Chemical, Petroleum, or Coal Products
8	Clay, Glass, Concrete, Stone, and Leather
9	Machinery and Metal Products
10	Miscellaneous

Because state economies differ dramatically, the commodity groups that are found to be important in one statewide freight model bear little correspondence to those found to be important for another statewide freight model. Due to the differences in state economies, not only the commodity groups but also the production and attraction equations tend to be unique to each statewide model. The production and attraction equations typically forecast multimodal commodity flows in tons based on some explanatory variable such as employment or population. In order to account for changes in the economy over time, several of these models include labor productivity as an input into these production and attraction equations.

The distribution of commodity productions and attractions between the zones in a statewide freight model is most typically forecast in Four-Step Freight Models through the use of a gravity model. Because of the long distances involved in distribution decisions, and because freight costs and time at a national level are highly correlated with distance, it is not surprising that the distance between zones is most often chosen as the impedance variable in the gravity model. Friction factors between the zones typically follow a negative exponential distribution, which means that the average distance traveled by a commodity between all zones provides an appropriate deterrence coefficient. That average distance can be found by merging the commodity flow survey with a distance skim table and using the combined data to provide the average trip length.

While the commodity flow survey could be used as a Revealed-Preference (RP) survey to assist in the development of Mode Choice equations, the available calibration data for nonhighway modes, or for long-distance truck highway freight modes, is not typically available. Therefore, even in Four-Step Freight Models, the Mode Choice step is typically the application of the existing mode splits, by commodity and origin destination pairs, as observed in the Commodity Flow Survey, or some ad-hoc modification of those mode shares, which is identical to the treatment described earlier for Direct Commodity Table Freight models. Additionally many of the influential factors in mode choice, as identified in the literature, cannot be readily computed as performance measures/utilities by the network models. For example, reliability is not customarily available from network models and yet it is cited as one of the most influential factors in freight mode choice. Additionally, even if a freight mode choice model indicates that a mode shift is warranted based on a change in modal utilities, long-term freight contracts may preclude freight from switching modes.

Similarly, the issues of converting annual flows from the computed modal truck trip tables to daily truck trips are the same as discussed earlier for Direct Commodity Table Freight Models. The annual conversion must account for average midweek travel, where a factor of 306 days per year is a suggested factor. The conversion from truck tons to truck vehicles requires the use of payload factors, in the same manner as discussed earlier for Direct Commodity Table Freight Models.

Assignment issues for Four-Step Freight Models are the same as for Direct Commodity Table Freight Models as well. This should not be surprising since the two categories only differ in the source of the modal trip tables, acquired or computed, and the treatment in assignment will be identical. For freight truck assignment, if performance needed, the assignment should be multiclass, including nonfreight trucks and autos. The derivation of nonhighway freight tables are needed to determine freight truck tables, but may not actually be assigned. If they are assigned, appropriate network and assignment procedures are needed as discussed previously for Direct Commodity Table Freight Models.

Validation

The validation issues concerning use of truck counts discussed previously for Truck Model validation also apply for the Four-Step Freight Models. An additional complication is that while traffic counts include all trucks, the freight trucks forecast by a Four-Step Freight Model are only a subset of all trucks. In all cases the assigned freight truck volumes should be less than the total truck counts, but without additional information, it may not be possible to separately validate commodity truck volumes against truck counts. If the Four-Step Freight Model also includes the forecast of nonfreight trucks, it may be possible to validate the total assigned volume against total truck counts, without being able to demine how well either the freight or nonfreight truck components are validated. Other studies[24] have found that only about half of light goods vehicles carried freight. This result is consistent with observations of the FAF highway network. Freight trucks constitute a larger share of total trucks on intercity routes in mostly rural areas. The validation of freight trucks against total trucks might be

[24] Holguín-Veras, J., and G. Patil (2005) *Observed Trip Chain Behavior of Commercial Vehicles*, Transportation Research Record No. 1,906.

more productive on those routes where they would be expected to be the vast majority of total truck volumes.

As was discussed for Direct Commodity Table Models, if an additional commodity flow database is available which is different from the commodity flow database used to calibrate the four-step model, it should be possible to assign that different commodity flow database to the highway network. Then, as was discussed previously, it should be possible to check for consistency between the assigned flows from the Four-Step Freight Model and the alternative flows from that other commodity flow database. For example when the Four-Step Freight Model is developed using the TRANSEARCH database as a calibration survey, it may be possible to compare the assigned freight truck volumes from the Four-Step Model with those assigned using the FAF2 databases. This is not truly validation unless the assignment of truck flows in the assigned of the different commodity flow database has itself been validated.

Similarly if another commodity flow database is available, the forecast of non-highway freight flows from the Mode Choice component of the Four-Step Freight Model can be compared to the nonhighway modal flows from that other database. In the event that the survey and comparison database are the TRANSEARCH and FAF2 databases, it should be remembered that the commodity classification systems used in these databases are different and do not match directly. Therefore the validation of nonhighway modal shares and flows might be appropriate only for total flows across all commodities. It should be remembered that the Surface Transportation Board's Carload Waybill Survey of railroad flows is directly included in both TRANSEARCH and FAF2, and thus should not be considered to be separate databases for validation purposes.

Also, if another commodity flow database is available, the trip length frequency distribution (TLFD) or an average trip length (ATL) from the Trip Distribution component of the Four-Step Freight Model can be compared to those from another database. As was noted previously, if the survey and comparison database are the TRANSEARCH and FAF2 databases, it should be remembered that the commodity classification systems used in these databases are different and do not match directly. Therefore the validation of average trip length and trip length frequency distribution might be appropriate only for total flows across all commodities.

If a commodity flow is available from a year prior to the one used as a calibration survey, and the socioeconomic and network characteristics data are available for that same prior year, it would possible to use the model to "backcast" freight flows and to validate these flows against the flows in the prior year commodity flow database.

5.6 Economic Model

Goal: The ability to forecast the interaction between the performance of the transportation system and economic activity, and to use the shipment of freight in support of that economic activity to develop forecasts of freight trucks, and possibly forecasts of other nonhighway modes.

Economic Freight Models typically forecast the extent and geographic location of employment and other economic activity in a region. They can be considered as counterparts to land use modeling which forecast the locations of residential and other socioeconomic data. In the course of forecasting economic activity, the demand for industries produced in the region is distributed to customers in other regions outside of the study areas (e.g., outside of a state).

Similarly, the demand by customers in the region is distributed from industries in other regions outside of the study area. This distribution will be based on the cost of producing and supplying goods, including the transportation costs between regions. The cost of transportation can be those developed in a conventional travel demand model. Additionally, the trade flow between regions, as well as the trade flows to zones within the region, can be considered identical to the freight trip tables discussed in earlier sections. All that is necessary for their use as trip tables in the assignment process is to convert flows, which might be expressed as dollar flows to units which can be more normally included in travel demand models.

Network Structure issues for the Economic Freight Model category are the same as discussed above for the other model categories. This model category is distinguished by the development of productions or attractions, or flows between zones, or by mode, resulting not merely as a result of Trip Generation, Trip Distribution and/or Mode Split, but through the use of an economic model which calculates the interaction between industries and the flows of commodities between these industries. In these models the flow units may not be tons as discussed above but monetary values, in which case a value per tons table may be needed to convert flows to comparable units. This might be done in concert with a land use model for residential and passenger modeling.

The operation of such a model may require policy decisions, such as economic development and education and employment strategies, which are not typically the jurisdiction of state DOTs. It also may require access to data, such as industrial employment data and forecasts at detailed levels, which might not typically be available to state DOTs. The most well-developed example of a state using an Economic Freight Model, in addition to the freight component of the draft Ohio State Model, is Oregon. It is noted that in addition to its economic growth functions, the Oregon model also builds tours of commodity movements.

Validation

As noted previously, an Economic Freight Model might be considered to be a Four-Step Freight Model with an economic forecasting component. Therefore all of the validation issues discussed for Four-Step Freight Models also apply to Economic Freight Models. Additionally, to the extent that the freight flows are estimated from the exchange of economic value between zones, these exchanges might be validated against tax receipts, industry payrolls and other economic data.

5.7 Data Sources for Freight Model Validation

In the informed opinion of the authors, the following are some suggestions for "good practices" that should be considered in the development of statewide freight models. These suggestions take into consideration how these models may be constructed, the data which may be available to develop and calibrate these models, and the data which may be available to validate these models. As noted previously, the variability in the calibration data, which is inherent and not likely to be sampling error, means that freight models cannot be expected to be validated to the same precision as passenger models.

Commodity Flows

Section 9.0 of the QRFM II[25] provides a comprehensive listing of sources of multi-modal and modal commodity flow databases. For the most part these databases are publicly available, the major exceptions being the commercially available TRANSEARCH multimodal commodity database and the STB's confidential rail-road Waybill Sample which is restricted to use by state DOTs and their designees. Care must be taken in utilizing any of these databases for validation to understand the contents and limitations of these databases.

Each of the databases has its own definitions of zonal geography, which is unlikely to be exactly the geographies desired for validation, and thus care must be taken to disaggregate or otherwise make the geographies compatible. Most of the databases use different definitions of commodity classifications and cross-walks may be necessary to compare among the databases. The coverage of the databases may be of all freight moving between the zones which are included, as in the FAF, or may include only flows to, from or passing through a defined core area, as in TRANSEARCH.

The databases may include linked modal trips, such as truck-rail trips in the FAF, or be unlinked modal or sub modal trips as in TRANSEARCH which reports

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[25] Cambridge Systematics, Inc., *Quick Response Freight Manual II*, FHWA-Office of Freight Management and Operations, September 2007, http://ops.fhwa.dot.gov/freight/publications/qrfm2/sect09.htm.

movements unlinked by mode (e.g., a truck-rail-truck trip would be reported as three records, one for each mode and geography or the STB Waybill Sample which reports movements by rail waybill, and two or more waybills may be needed to define a complete trip). Understanding the contents of the database and making all records consistent with the manner in which flows are reported in a freight forecasting model are vital before using any commodity flow database for validation.

The commodity flow databases should not be viewed as perfect and complete. TRANSEARCH is individually prepared for each purchase and errors may have been made in preparing the database. Both FAF1 and FA2 had indentified errors in commodity and geographic reporting and the FAF3 which was released in July 2010 may have as yet undetected errors. The Carload Waybill Sample is, as stated in the name, an expanded sample, not a 100 percent representation of tonnages.

Finally, despite the names, the commodity flow databases for different years should not be used as an accurate time series of freight flows. The STB Commodity Flow Survey over time has used different sampling procedures, and while it has been consistent since 1997, the CFS for prior years used different zonal definitions and commodity classifications. TRANSEARCH cautions that its data collection procedures have improved with each release and that differences from prior databases might be due to changes in collection and reporting methods, and not changes in freight flows. Before using commodity flow databases to validate a freight forecasting model, it is always wise to perform quality control checks on that data to ensure accuracy and consistency with the definitions of the freight forecasting model.

Networks

The detailed highway networks in statewide freight models will typically be the same as the highway network used in the statewide passenger travel model. For the area serving zones beyond the primary focus of the statewide passenger model, modal networks are available from a variety of sources as described in QRFM2. These national networks include the FAF network available from FHWA and modal networks available from the Oak Ridge National Laboratory's Center for Transportation Analysis.

Truck Counts

Validation of statewide models to observed data typically means validating the model results to observed truck counts. As discussed previously, freight models will forecast freight trucks, which are a subset of the total trucks observed. Additionally, the classification counts which are available may need to be adjusted to the same time period covered by the model (e.g., average weekday or average annual daily traffic). Additionally, the measurement units in the freight model (e.g., trucks by weight) may need to be converted to other classification systems used in observed classification counts, such as FHWA's Scheme F Body

Type and Axle-Based Vehicle Classification System as recommend in FHWA's Traffic Monitoring Guide.[26]

While forecasted freight truck volumes should always be less than observed truck counts, more attention in validation may be placed in rural locations on Interstate highways and other principal arterials where there are few nonfreight trucks and freight trucks should be the dominant flows.

Categories of Outputs

It needs to be recognized that the use of freight models in various benefit/cost or environmental software may require a specific classification of trucks, by operation, weight, length, etc. It will typically be difficult to validate the freight model to these categories, and it might be preferable to post process the model forecasts to meet the needs of other analyses, rather than forcing the model to produce outputs which could not be validated.

Inclusion of Nonfreight Trucks

The calculation of truck performance, or the consideration of truck impedances of congested times, cost, or reliability, require the inclusion of nonfreight trucks in freight models. All trucks, including nonfreight trucks, are the subject of the Truck Model category of freight models. Most Direct Commodity Table and Four-Step Freight Models include calculation of nonfreight trucks. Citilabs' CARGO[27] model, which is a standardized product for forecasting freight volumes, specifically includes a SERVICE Module to calculate these service, commercial delivery, maintenance, construction, and other trucks separately from and added to freight truck volumes. The Pennsylvania Freight Model is an example of a Four-Step Freight Model that uses CARGO. The preceding discussion is meant only to show at that least one standardized freight model platform acknowledges the need to include a separate calculation of nonfreight trucks. It is not an assessment of how these calculation are done.

Distribution Centers and Other Freight Transportation Logistics Centers

Freight trips often use more than one mode during the trip between the ultimate origin and final destination, and change modes at intermodal rail, water, air, or other logistics centers. Additionally, the flow of freight even within one mode (e.g., truck), may pass through one or more Distribution Centers during its path between the ultimate origin and destination. This situation can be considered to be analogous to the use of transit stations in passenger models, including access

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[26]Office of Highway Policy Information, *Traffic Monitoring Guide*, FHWA, May 1, 2001.

[27]http://www.citilabs.com/cube_cargo.html.

links by different modes. The proper accounting for these trips in freight models is as challenging accounting for multileg trips in passenger models.

The validation of modal shares requires the treatment of the entire multimodal trip and needs to acknowledge the costs of travel to and from these distribution/ intermodal logistics centers. However, the assignment step needs to account for each leg of the modal trips separately. While this process may be challenging to model, it also provides the opportunity to develop additional validation data. The freight moving through these logistic centers, both in total, and to and from various markets, may be available as additional validation data from the operators of those facilities.

It should be noted that the freight flow databases which might be used in model calibration or validation may treat these logistics centers in a variety of ways. A modal database of freight flows may not include flows taken to access those modes and also may not include intermediate transfer points along the path for that mode. Some multimodal freight databases, such as IHS/Global Insight's TRANSEARCH database, report each modal leg separately and thus are properly flows between logistics centers and not the ultimate origins or destinations. They also do not indicate how the legs of a multimodal trip are connected.

This may be a plus in the assignment of trips but may create difficulty in use for other model steps. Other multimodal freight databases, such as the Commodity Flow Survey and the Freight Analysis Framework, include only the ultimate origin and destination and provide no information about the various legs of each trip, including where modal transfers are made.

Some roadside intercept surveys, for example the 1999 Canadian National Roadside Study, the Ontario Commercial Vehicle Survey, and Commercial Vehicle Intercept Surveys conducted by the Canada-United States Transportation Border Working Group and the Port Authority of New York Hudson River Crossing Truck Intercept Survey, include indications of the use of distribution centers as the prior or next stop. Practitioners may wish to acquire these data and other intercept surveys for use in validation if it is thought that the freight model should exhibit similar behavior.

6.0 Statewide Integrated Transportation/Land Use Models

One of the advances in statewide modeling in recent years has been the development of integrated transportation/land use models. Such systems remain more common at the MPO or regional levels of geography than the statewide level; however, there has been considerable progress in integrated statewide models over the past several years. Efforts to develop such models at the statewide level are now becoming commonplace. That trend is expected to continue as decision-makers strive to understand the externalities of transportation investments and land use policy strategies. Increasingly statewide planners are asked to explain the effects of transportation investments on a wide variety of topics including:

- Air quality;
- Economic development;
- Commodity flow;
- Quality of life; and
- Transportation investment demands resulting from land use policies.

While state DOTs continue to advance the development of integrated models, validation of such models has little in the way of published materials to date. This topic is addressed in more detail at the end of this section, by presenting some of the validation efforts and findings from a case study of the Oregon statewide model.

6.1 Overview

Reasons cited for the addition of a land use model component to the forecasting tool box are as varied as the states. Consistent objectives shared amongst all the reviewed models include the need to:

- Ensure transportation models can represent realistic land use market responses and transportation demands to major investments in areas outside of urban area models' geographic coverage;
- Assure a degree of consistency in land use data and forecasts used to drive transportation models; and
- Add ways to quantify policy implications of state DOT and other state agency actions (such as controlling greenhouse gas emissions). These

demands often fuel subsequent refinements to the models at least as much as the need to refine model performance.

All the states reviewed integrate the land use and transportation models using a feedback-based approach. The land use model approaches employed to date in statewide models are built on the following theoretical frameworks:

- **Logit-Based Location Choice –** Analytical models founded on the concept of spatial separation or accessibility similar to a gravity model used in many four-step transportation models; and
- **Input/Output (I/O) –** Analytical models based on economic flow theory (production/consumption of goods and services).

States where economic issues are seen as critical tend to follow the more data intensive input/output approach whereas states that do not have that same perceived need tend to use a logit-based (or gravity-type) approach. The following subsection describes these states' efforts, the reasons cited for the effort and where possible, their current status, and planned upcoming efforts.

The states that have undertaken some stage of integrated model development are presented in Table 6.1. What is noteworthy is that none of the models reviewed are considered "completed" per se as they are in a constant evolutionary state of development, application, evaluation, further development, etc. Oregon DOT has the only integrated model that is in its second generation of application. On the other end of the spectrum is the Texas model which is still in the exploratory phase of development.

6.2 State-by-State Review

The initiative behind the development of the statewide integrated models documented in this chapter seems to have a common set of themes. In California and Oregon the development of the integrated model framework was mandated by state law and/or strong political pressure. Florida and Ohio developed their models to meet the needs of a statewide agency with support from a large model user community. Indiana and Texas started off as funded University research projects that have been adopted by their respective state DOTs.

This subsection presents an overview of existing statewide integrated transportation/land use models and their key features, with states organized in alphabetical order.

Table 6.1 Integrated Statewide Transportation/Land Use Model Efforts

State	Status	Developer	Transportation Model Type	Land Use Model Type
California	First Generation – In Development[28]	UC Davis and HBA Specto	Enhanced Four-Step	Economic Input-Output (PECAS)
Florida	First Generation – In Application[29]	Florida's Turnpike Enterprise and Resource Systems Group	Origin-Destination Matrix	Gravity/Logit Choice
Indiana	First Generation – In Application[30]	Purdue University Indianapolis	Four-Step Model	Gravity/Logit Choice
Ohio	First Generation – In Application[31]	PBQ&D and HBA Specto	Tour-Based Model	Economic Input-Output (PECAS)
Oregon	Second Generation – In Early Application Testing[32]	PBQ&D and HBA Specto	Tour-Based Model	Economic Input-Output (PECAS)
Texas	Predevelopment of a First Generation[33]	UT Austin	Enhance Four-Step	Economic Input-Output (PECAS)

California

The California integrated model development effort is a response to recent laws passed in the State that require an assessment of land use response to transportation investments particularly as it relates to greenhouse gas and other emissions. The goal of the project is to develop an integrated interregional model that

[28] University of California Davis. *Statewide Integrated Interregional Land Use/Economic/Transportation Model.* Retrieved from Information Center for the Environment: http://ice.ucdavis.edu/project/statewide-trans-model, May 2009.

[29] Lawe, S.; Lobb, J.; Hathaway, K. *Statewide Land-Use Allocation Model for Florida.* White River Junction, Vermont, May 2007.

[30] Ottensmann, J. R. & Palmer, J. L. *LUCI Model Aids Planning for Transportation Planning and Other Infrastructure.* Central Indiana (pp. 1-8), July 2004.

[31] Giaimo, Gregory T., Ohio Department of Transportation. *Statewide Model Update.* Presented to the OTDMUG, September 20, 2007.

[32] Weidner, T.; Knudson, B.; Hunt, J. A. *Sensitivity Testing with Oregon Statewide Integrated Model (SWIM2).* Prepared for Transportation Research Board 2009 – Update, 2009.

[33] Juri, N. R. & Kockelman, K. *Extending the Random-Utility-Based Multiregional Input-Output Model: Incorporating Land-Use Constraints, Domestic Demand and Network Congestion in a Model of Texas.* Prepared for the 2004 Annual Meeting of the Transportation Research Board, 2003.

can be used to better understand various infrastructure investment proposals and policy options.

In 2007, the Information Center for the Environment at UC Davis, with funding from the California DOT, was exploring the feasibility and benefits of the potential implementation of a statewide integrated land use/economic/transportation model. This type of model would have the ability to assess the interregional effects of major changes to land uses, economics, and transportation on energy, the economy, and the environment in a variety of ways,[34] including the following:

- Costs and benefits of major infrastructure investments;
- Travel between California's regions and counties;
- Habitat and species protection strategies;
- Preservation of agriculture areas;
- Clean Air Act policies and programs;
- Clean Water Act compliance;
- Economic development programs;
- Jobs/housing proximity;
- Various housing policies and programs;
- Redevelopment and urban infill strategies; and
- Regional job production and job creation programs.

Model development has continued since 2007 but is not yet complete. It is expected that the model will integrate a PECAS-type land use allocation process, economic models and the general statewide passenger and goods movement models.

Client: California DOT (Caltrans)

Reported Project Cost to Date: $5,000,000 to $10,000,000 (plus $5,000,000 for data collection)

Current Status: In Development

Next Steps: Estimation, Calibration, Validation, and Deployment

Status of Model Validation: Model validation procedures and targets have not yet been developed and are pending completion of the integrated model. Early efforts have focused on updating and refining the transportation model.

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[34] University of California Davis. *Statewide Integrated Interregional Land Use/Economic/ Transportation Model.* Retrieved from Information Center for the Environment: http://ice.ucdavis.edu/project/statewide-trans-model, May 2009.

Current Status and Upcoming Efforts: Caltrans is developing a household survey in coordination with the State's MPOs that will be used to support the development of the integrated model and other modeling efforts. It is expected that the integrated model project will be completed in 2012.

Florida

In 2005, Florida's Turnpike Enterprise began development of a new statewide travel model that could be used to test the feasibility of potential intercity toll facilities that extended beyond the boundaries of available urban and regional travel models. The issue driving the development of this model was the need to develop a consistent, defensible process for developing traffic and corresponding revenue forecasts for Turnpike's projects throughout the State.

Client: Florida's Turnpike Enterprise

Reported Project Cost to Date: < $1,000,000

Next Steps: Integration with FDOT General Statewide Model

Model Overview: This model was a custom development effort built around a logit choice-based custom framework in which the model components rely directly on databases that are being maintained by a variety of other parties. Given the scale of effort needed to abstract from and integrate these data, the demand model structure was kept simple but designed to incorporate elements that provide the needed functionality: a GIS-based network, a simple travel demand modeling procedure and a simplified but integrated land use model.

Status of Model Validation: The Florida model has been validated sufficiently to meet the broad purposes of Florida's Turnpike Enterprise. Sensitivity tests show that with the baseline dataset, the model achieves a 0.93 R-squared value when comparing 2015 independent population forecasts at the county level. Detailed assessment of model outputs has identified difficulties matching observed development patterns at the zonal level due to the "lumpy" nature of development patterns compared with the broader development likelihood assumptions employed by the model.[35]

Current Status and Upcoming Efforts: In 2009 RSG began the process of adapting the statewide land use model to the Florida DOT (FDOT) general statewide model. First steps of the integration were completed by the end of 2009. Subsequent efforts will focus on adding richer capabilities, additional validation efforts and some application testing. The integration of the land use model with the transportation model for general statewide application is being driven in part from a recent model user survey that identified the need for an

[35] Lawe, S.; Lobb, J.; Hathaway, K. *Statewide Land-Use Allocation Model for Florida.* Resource Systems Group, May 2007.

integrated framework as one of the top three priorities of model users in the State.

Indiana

The Indiana DOT had a statewide model and wanted to explore potential land use interactions with major upcoming transportation project proposals. After reviewing several possible candidate land use submodels, they selected *LUCI*. The original *LUCI* model was a simplified land use allocation model developed to help policy-makers, planners, and citizens understand the effects of policy choices on patterns of urban development by developing an analytical framework to forecast future urban development for a 44-county area in central Indiana. The model predicted the quantities of land that were not urban in 2000 that will be converted to urban uses as far out as 2040.[36] *LUCI* and the statewide model were subsequently integrated to create the "**IN**tegrated **TR**ansportation **L**and **U**se **D**emand **E**stimation" model, INTRLUDE.

Client: Originally funded by an award of general support from the Lilly Endowment, subsequently funded by the Indiana DOT

Developer: Purdue University Indianapolis, Center for Urban Policy and the Environment

Reported Project Cost to Date: Unknown

Model Overview: INTRLUDE is designed to predict future urban development in five-year increments and to establish feedback between changes in transportation accessibility and land use development potential. Each simulation period starts with a specified amount of population growth for the entire region that must be accommodated. The model predicts the probability of development and density for each grid cell using the two equations, one for businesses and one for residential development. Final amounts of new urban development are then determined by adjusting these tentative predictions up or down to accommodate the specified population growth. Since the original *LUCI* model was developed several enhancements were implemented thereby creating the *luci2* and integrated into INTRLUDE. The major extensions included the separate simulation of new residential and employment-related development and the forecasting of future levels of economic activity (employment).

The integrated INTRLUDE framework allows for the testing of transportation impacts on land use allocation. VMT estimates in the statewide model previously were insensitive to land use changes that resulted from projects. Further it was difficult to incorporate TAZ-level revisions that would result changes in

[36]Ottensmann, J. R. & Palmer, J. L. *LUCI Model Aids Planning for Transportation Planning and Other Infrastructure.* Purdue University (pp.1-8), July 2004.

macroeconomic conditions such as the recent economic downturn. Applications of INTRLUDE include:

- Indianapolis outer loop expressway;
- U.S. 31 upgrade to limited access;
- I-69 new terrain/upgrade; and
- Illiana expressway.

Summary of Model Validation: To validate the model, the calibrated model was used to convert Area Plan Commission (APC) future-year demographic and economic values into land use patterns. Because INTRLUDE (previously referred to as Integrated Transportation Land Use Modeling System or ITLUMS) incorporated expected transportation changes into its forecasts and the APC did not, a direct comparison of the forecasted land use patterns could not be made. However, the direction and magnitude of the differences between the INTRLUDE and APC forecasts were deemed acceptable by the APC. In addition, ITLUMS underwent further tests using scenarios of special interest to the APC, providing further opportunities to assess the value of INTRLUDE as a planning tool (Yen & Fricker).

Current Status and Upcoming Efforts: The advancement of a statewide version of the model for the Indiana DOT (INDOT) and the integration of the model with INDOT's travel demand model was the most recent advancement.[37] The INTRLUDE model simulates residential and employment-related development and predicts local service employment for the TAZs in the travel demand model, for the entire State. This was then integrated with the travel demand model to simulate both urban development and travel, with the models passing data back and forth in five-year simulation periods to capture the interaction between transportation and land use.

Ohio

The development of the Ohio integrated statewide transportation/land use model was precipitated by a user needs study that indicated that understanding how transportation investments effect economic development was one of the top three issues that needed to be addressed by the statewide model. Other important issues driving the development of the model was the need for a consistent approach to forecasting land use across the entire State and the need to evaluate

[37] Ottensmann, J. R.; Brown, L; Flicker, J. & Jin, L. *Incorporating a Land Consumption Model with a Statewide Travel Model*. Prepared for the 12th TRB National Transportation Planning Applications Conference, 2009.

large-scale land use impacts of transportation investments without a heavy reliance on local, and often nuanced, knowledge.[38]

Client: Ohio DOT (ODOT)

Reported Cost to Date: $1,000,000 to $2,000,000 (approximately additional $4,000,000 for data collection)

Model Overview: Version 1 of the Ohio Statewide Model included no land use model. Version 2 of the model had a simplified structure which was scaled back from the original PECAS-based attempt (at Version 2). However, that original attempt was never fully implemented.[39]

Summary of Model Validation: Several of the Ohio models' modules include auto-calibration routines to meet specific target data sets. As the model is not fully developed as envisioned specific calibration and validation performance metrics have not been fully developed or documented as of the date of this publication.

Current Status and Upcoming Efforts: Currently, the simplified land use model is being refined and tested. Difficulties in developing consistent statewide data to estimate and apply the model and staffing limitations prevented a final version of the model from becoming fully operational at the date of this publication. Version 3 is envisioned to attempt to implement a PECAS-type model or some other enhanced process. Further development in Version 3 also has been hindered by the difficulty identifying staff and funding resources necessary to develop detailed models in the current economic climate and a general lack of detailed data on a statewide basis necessary for a more detailed land use model. In the immediate future, it is expected that some incremental improvements may be made to the Version 2 model to meet short-term needs.

Oregon

Legislative and political actions in Oregon mandated consistent and scalable analysis tools for studying the interaction of land use, transportation, and the environment. Oregon's model has been applied to statewide, regional, and corridor planning studies to help inform decision-makers and the public about land use and transportation tradeoffs resulting from prospective public policy actions. As the oldest of the statewide integrated models, Oregon's experiences have had sufficient time to be thoroughly tested and used successfully in "real world" applications.

Client: Oregon DOT (ODOT)

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[38]Giaimo, Gregory T., *Telephone Interview* by W. White (2009).

[39]Giaimo, Gregory T., Ohio Department of Transportation. *Statewide Model Update.* Presented to the OTDMUG, September 20, 2007.

Reported Cost to Date: $5,000,000 to $10,000,000

Model Overview: The Oregon DOT has in place a Transportation and Land Use Model Integration Program that is designed with the purpose of building a set of consistent and scalable analysis tools for studying the interaction of land use, transportation, and the environment. As the first statewide implementation of an integrated model chain (Statewide Integrated Model, aka SWIM), the Oregon Statewide Model has had the benefit of a history of testing and refinement. The first generation model was used for a number of important and high-profile planning studies. Experience with this model helped to inform the development of the second generation model (SWIM2).

The dimensions and extent of the model can be gleaned from a description of the model's categories during a recent conference presentation:[40]

- **Activities** (11 different activities broken down by 18 household income/size categories, 20 industrial sectors);
- **Commodities** (42 commodity groups, 8 occupations, 15 services, 19 floor space types);
- **Modes** (Auto: drive alone, shared ride, Urban transit: Portland, Eugene, Medford, Salem, Corvallis, Intercity passenger: air, Amtrak, intercity bus, Nonmotorized: walk, bicycle, Freight: 5 truck weight classes, air cargo, railroad, water, pipeline); and
- **Road Network** (approximately 40,000 links, 2,950 "alpha" zones).

The SWIM2 model allocates activities to land in steps through time with a simulation preferably occurring yearly. The model supports up to five truck classes, which can be collapsed depending on the focus of a particular model run and related issues. Overall, modelers are satisfied with the quality of the calibration and the reasonableness of the model's sensitivity. The model is being applied to its first major corridor study.

Summary of Model Validation: At a presentation to the fifth Oregon Symposium on Integrating Land Use and Transportation Models, model developers presented some broad conclusions about the state of the Oregon model:

- Model is performing reasonably well.
  - It is broadly hitting key targets.
  - Not perfect…
  - Not expecting to hit every target exactly (target inconsistency, wide scope in integrated model).

[40] Weidner, T.; Knudson, B.; Hunt, J. A. *Sensitivity Testing with Oregon Statewide Integrated Model (SWIM2).* Prepared for Transportation Research Board 2009 – Update, 2009.

- Recognizing calibration is never "done."
- Timing forcing us to move on…
- Current model sufficient for sensitivity tests.
  - Relative measures.
  - Appropriate to consider model response.
  - Revisit some calibration measures.

Current Status and Upcoming Efforts: Ongoing efforts to develop and refine the Integrated Model are promoted through the Transportation and Land Use Model Integration Program. The SWIM2 model has recently become operational and is being applied to the development of a statewide freight plan. In addition, it will soon be used to develop forecasts of external travel for metropolitan areas.

Texas

The University of Texas Austin recently developed the RUMBRIO modeling framework (Zhou & Kockelman, 2003).[41] RUMBRIO was conceived to address the need to incorporate economic flow information into the traffic forecasting process. The model is being examined for full integration into the Texas Statewide Model but that process had not been completed as of this publication date.

Client: Texas DOT (TXDOT)

Reported Cost to Date: < $1,000,000

Model Overview: RUMBRIO belongs to a class of land use-transportation models that make use of spatial input-output (SIO) models, some of which are based on random-utility theory. The random-utility-based multiregional input-output (hence RUBMRIO) model has been solved in practice by iteratively applying a set of equations. Each of the model equations describes relationships among key model variables.

Summary of Model Validation: Available documentation suggests that model validation has focused on goodness-of-fit of model parameters and coefficients. As the model moves towards a greater number of applications, more detailed assessments will be made to assess calibration and validation.

Current Status and Upcoming Efforts: The RUMBRIO model approach has been used for very large corridor studies in Texas. Additionally RUMBRIO has been applied to statewide economic impact assessment across the entire State of

[41] Zhou, Y. and Kockelman, K. M. *The Random-Utility-Based Multiregional Input-Output Model: Solution Existence and Uniqueness*. Transportation Research Record Part B 38 (pp. 789-807), 2004.

Texas.[42] The original RUBMRIO model was extended to recognize land use constraints on production (and residence), to incorporate "domestic demands" by other U.S. states, to estimate vehicle trips resulting from monetary trades, and to capture the effects of the network congestion on trade and production decisions. It is anticipated that future efforts will focus on the refinement of the model and further integration of it into the statewide transportation model.

6.3 Validation of Integrated Transportation/ Land Use Models

Validation is a complex process in both transportation and land use models and in integrated models it presents an even more challenging set of issues. Only Oregon's efforts are sufficiently mature to have documented evaluation metrics and the resulting performance of the integrated model. The various contexts and states of development of the integrated models presented in this document suggest that validation is still in its infancy compared with stand-alone statewide transportation models. DOTs and researchers are still in the process of establishing calibration and validation criteria that must be met to provide some degree of certainty that these models are suitable for policy analysis.

Oregon's first generation of integrated models pursued the issue of calibration and validation and concluded "(a) surprising finding of the research into current practice was that no clearly defined model calibration or validation criteria existed for integrated land use-transportation models."[43] While the performance criteria for transportation models are fairly well-documented, the same cannot be said for land use models and integrated models, even to this day.

Oregon started with relatively few performance metrics for the first generation model. Measures for absolute (base year) and incremental performance (change in trip-making) were set at +/-20 percent. Because Oregon was the first integrated statewide model, validation focused on the reasonableness of absolute values and their sensitivities.[44]

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[42] Juri, N. R. & Kockelman, K. *Extending the Random-Utility-Based Multiregional Input-Output Model: Incorporating Land-Use Constraints, Domestic Demand and Network Congestion in a Model of Texas.* Prepared for the 2004 Annual Meeting of the Transportation Research Board, 2003.

[43] Parsons Brinkerhoff Quade & Douglas. *Transportation and Land Use Model Integration Program: Overview of the First Generation Models.* Prepared for Oregon Department of Transportation, 2001.

[44] Ibid.

Application experience from the first generation model resulted in the development of more rigorous performance criteria for all aspects of the second generation model that could be used to test how well the model reproduced not only the base condition but a five-year forecast window that could be used to calibrate model parameters and validate the integrated model's performance for 1990 to 1995. As shown in Table 6.2, the second generation of the Oregon Model (Oregon2TM) has an established set of calibration metrics and targets for many aspects of the latest version of the integrated model.[45]

Table 6.2 Oregon2TM Calibration Metrics and Target Data[46]

Type	Calibration Metric	Target Data
	Economic and demographic (ED) module	
Primary	Oregon activity ($) by industry	1990 to 2000 U.S. Bureau of Economic Analysis (BEA)
Primary	Oregon employment by industry	
Primary	Oregon employment x industry (NAICS)	1990 to 2011 Oregon Office of Economic Analysis (OEA)
Secondary	Oregon 2000 to 2040 activity/emp growth rates	No target
Secondary	2000 to 2040 Res/NonRes Construction Dollars	No target
	Synthetic population generator (SPG)	
Primary	Modelwide HHs by income/size category	1990 and 2000 U.S. Census PUMS
Secondary	Modelwide HHs by income/size category	1990 and 2000 U.S. Census STF3
Secondary	MPO HHs by income/size category	2000 U.S. Census STF3
	Aggregate land development (ALD) module	
Primary	County change in building stock (sqft) by type	1990 to 2000 FW Dodge Building Stock
	Production allocation and activity interaction (PI) module	
Secondary	Vacancy rates by type by ALD region	1998/1999 Real Estate Reports ($/bldgsqft) Early 1990s Tax Assessor Data ($/landsqft)
Secondary	Trip lengths (modelwide average) – Person by purpose/occupation – business/service by sector – goods by commodity	1994/1996 Household Travel Behavior Survey 2003 Ohio Establishment Survey 1998 Oregon Commodity Flow Forecast and 1997 U.S. CFS
Primary	Oregon County-County labor flow ($)	2000 Census CTPP

[45] Oregon Department of Transportation. *Oregon2TM Full Model Calibration Summary.* June 4, 2008.

[46] Parsons Brinkerhoff Quade & Douglas. *Oregon2TM Sensitivity Test Workplan.* Prepared for Oregon Department of Transportation, June 2008.

Type	Calibration Metric	Target Data
Secondary	Modelwide goods flows ($) by commodity	1998 Oregon Commodity Flow Forecast (7 x too big) 1998 FHWA Freight Analysis Framework
Secondary	Modelwide Import/Exports by commodity ($)	1998 IMPLAN imports/exports
Primary	HHs by income/size category by betazone	2000 Census STF3
Primary	Industry output ($) by betazone	1998 IMPLAN-based (distributed using employment)
	Person transport (PT) module	
Secondary	Employment by industry sector and MPO	1998 IMPLAN County Employment 1990 Oregon REIS dataset
Secondary	LDT Total trips, by mode and Trip Distances	1995 American Travel Survey, Oregon data
Primary	Tours per pattern by person type	1994/1996 Oregon Household Travel Behavior Survey
Primary	Trips per tour by tour purpose and person type	1994/1996 Oregon Household Travel Behavior Survey
Primary	Trip mode by tour purpose and MPO	1994/1996 Oregon Household Travel Behavior Survey
Primary	Average trip length by tour purpose and MPO	1994/1996 Oregon Household Travel Behavior Survey
Secondary	Frequency of Tour departure time by tour purpose	1994/1996 Oregon Household Travel Behavior Survey
	Commercial travel (CT) module	
Secondary	Modelwide goods flows (tons) by commodity	1998 Oregon Commodity Flow Forecast (7 x too big) 1998 FHWA Freight Analysis Framework
Primary	Tonnage in/out of Oregon	2002 U.S. Commodity Flow Survey
Primary	Average truck trip length by commodity	1998 Oregon Commodity Flow Survey
Primary	Stops per tour by vehicle type by commodity	N/A
Secondary	Payload weight by commodity by truck type	N/A
	Transport supply (TS) module	
Primary	Traffic Counts (daily and period) – summed link flows RMSE by category – ATRs summed by screenline location – link flow comparison (all vehicles, truck)	1996 to 2002 ODOT ATR traffic counts (251 locations) 2004 to 2006 Metro Traffic counts/Truck counts MPO Traffic counts 2000 External Station Adj. State DOT ATR traffic counts
Secondary	Trip Length Distributions	No target
Secondary	Oregon daily VMT statistics (TBD)	HPMS State VMT by vehicle type Oregon State road VMT by county

The performance assessment of the Oregon model resulted in calibration of most aspects of the model to better fit observed data and trends. Oregon continues to evaluate the second generation model performance using a select set of scenarios to reveal the behavioral response of the Oregon2TM to changes in the economic, land use, and transport inputs/constraints.[47] Calibration is viewed as a critical part of the model development since model credibility largely depends on the ability to suitably validate the model with real-world observations. This work is viewed as necessary to fully prepare the Oregon2TM for policy analysis. Three primary types of tests are programmed to evaluate the model's sensitivity:

1. Stochastic variability;
2. Effect of capacity; and
3. Effect of vehicle operating costs.

For each of the tests, it is anticipated that a battery of alternatives will be tested. More than 75 sensitivity tests are scheduled in all.

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[47] Parsons Brinkerhoff Quade & Douglas. *Oregon2TM Sensitivity Test Workplan.* Prepared for Oregon Department of Transportation, June 2008.

7.0 Summary and Conclusions

This report has identified procedures and results on model validation and sensitivity analysis from technical reports on 30 different statewide models and other reference and research documents. Key findings from this review include the following:

- Most statewide models have been solely validated through the reporting of traffic assignment statistics, in comparison with accuracy standards for RMSE, R^2, and percent error (observed counts versus model estimates);
- The authors of this report believe that a lack of reported validation statistics for trip generation, trip distribution, and mode choice might be related to a prior lack of comparative statistics from other statewide models, such as those provided in this report;
- Lack of consistency in market sectors (trip purposes, transportation modes, commodities, etc.) also adds complexity to making comparisons across statewide models; however, there are some common threads for comparisons to be made;
- Variations in statewide model network and zone systems make it difficult to establish a typical range of ratios such as links per zone or population per zone, although the authors of this report recommend using lane-miles per zone as a means of potentially providing more consistent statistics;
- Relatively few states have conducted statewide household or intercept studies focused on travel model parameters and benchmark statistics for statewide model calibration and validation, which leads to questions about sources for trip rates, etc.;
- Percent trips by purpose are in similar ranges among statewide models, while the long-distance purposes typically account for less than one percent to almost three percent of all travel estimated in statewide models;
- Percent intrazonal trips are typically higher in statewide models than urban and regional models, due to larger zone sizes found in statewide models;
- Average trip lengths for typical urban model purposes (home-based work, home-based other, nonhome-based) are similar to those reported in regional models, although long-distance trip purposes show uniformly longer average trip lengths;
- There is no single consistent threshold for defining long-distance trips, with the minimum distance ranging from 50 miles or minutes to 100 miles or minutes, depending on the state; consistency with definitions used in the ATS and NHTS would seem appropriate for determining the thresholds for long-distance trips;

- Several statewide models report trip lengths in miles (rather than minutes of travel), something rarely done for urban and regional models;
- A majority of statewide models are "highway only" in the sense that travel demand by air, rail (passenger and freight), and water is not assigned to networks, thus limiting the availability of mode split statistics; however, it is not uncommon for freight mode choice models to split freight into transport modes yet only assign truck trips;
- The presence of a statewide logit mode choice model is largely based on the impact of transit modes in properly simulating existing travel patterns and plans for implementing intercity or high-speed rail in the future;
- Auto occupancy statistics are readily available for statewide models and tend to run higher than urban and regional models as longer-distance trips generally involve either family members or business colleagues traveling together;
- Traffic assignment RMSE for statewide models tends to track at higher levels than typically found in urban and regional models due to lower link volumes, larger zones, and relatively sparse networks;
- Both RMSE and percent assignment error statistics are summarized into a wide range of categories by volume group, facility type, etc., thus complicating the process of comparing results across multiple models;
- Highway assignment usually results in estimates of average annual daily traffic (AADT), with a few statewide models that forecast traffic by time-of-day and a small number that conduct assignment for peak weekends or seasons of the year;
- Relatively little information is documented on model sensitivity testing or the reasonableness of forecasts and any cyclical impacts on statewide model validation;
- Validation of freight models varies considerably based on key commodities in a given state, model structure, treatment of nonfreight trucks, ability to simulate distribution and logistics centers, and data availability on freight and trucks; and
- Statewide integrated transportation/land use models are largely in their infancy, with references found in only six states, and very little documented measurements related to validation and sensitivity testing.

Two useful products to enhance statewide model validity through consistency of assumptions, would be the development of a national travel demand forecasting model along with updated survey data on long-distance trip-makers. As noted earlier in this report, the FHWA has been looking into both of these issues via the newly established American Long-Distance Personal Travel Data and Modeling Program. This program would provide comprehensive data for states on external trip patterns and long-distance travel behavior and characteristics of travel.

Just as many years ago, when the field of urban travel demand forecasting was in its infancy, likewise the development of statewide models is a fairly recent phenomenon. As time goes by and more experience is gained from developing, validating, and applying statewide models, more statistics on model benchmarks and validity will become available. This report is a start in this direction.

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B. NCHRP Task 91 – List of Statewide Models Reviewed

1. Alabama (2005/2035)
2. Arizona (2005/2030/2050)
3. California (2000/2030)
4. Colorado (2000/2025)
5. Connecticut (2005/unknown)
6. Delaware (2003, 2005/2030)
7. Florida (2000/2030, 2005/2035)
8. Florida Turnpike Model (2004/2015)
9. Georgia (2001/2035)
10. Indiana (2000/2030)
11. Iowa (2000/2030)
12. Kentucky (1999/2030)
13. Louisiana (2000/2030)
14. Maryland (unknown)
15. Massachusetts (2000/unknown)
16. Michigan (unknown)
17. Mississippi (2000/2005-2030)
18. Missouri (unknown)
19. New Hampshire (2000/unknown)
20. New Jersey (unknown)
21. New Mexico (2005/2030)
22. Ohio (2000/2030)
23. Oregon (1990/2020)
24. Pennsylvania (2006/2030)
25. Rhode Island (2000/2030)
26. Tennessee (2003/2030)
27. Texas (1998/2025)
28. Utah (2005/2030)
29. Vermont (2000/2020/2030)
30. Virginia (2000/2025)
31. Wisconsin (2000/2030)
32. Model (Base Year/Future Year)

C. Available Statewide Model Summaries of Structure and Statistics

	Model Characteristics					Trip Generation		Trip Distribution					Mode Choice		Trip Assignment						Network		Sources	
State	Model Type	Rural or Urban Model	Socio-Econ & Socio-Dat	Zones	Links	Aggregate Trip Rates	Trip Purposes & %	Average Trip Lengths	Trip Length Frequencies	Coincidence Ratios	Intrazonal Trips	Terminal Times	Mode Split	Auto Occupancy Rates	RMSE	GEH	V-o-C Ratios by: VMT/VHT	V-o-C Ratios by: Area Type	V-o-C Ratios by: Facility Type	V-o-C Ratios by: Lanes	Area Type	Facility Type	Sources for Calibration	Sources for Model Information
Alabama	Four Step	Rural and MPO	[illegible]	1,081	6,807	[illegible]	HBW: 15.19; NHBW: 46.22; Other: 21.09; Truck: 7.79; External: 0.75												Freeway = 1.01; Principal Arterial = 1.05; Minor Arterial = 0.944; Collector = 0.87; All Links = 1.01		4 planning areas; Rural	Freeway: 1.01; Principal Arterial: 1.05; Minor Arterial: 0.94; Collector: 0.87	Four-Step Model: Calibrated using FHWA Model Calibration & Reasonableness Checking Manual. Woods & Poole emp data.	AL SWTP Plan 4/08
Alaska	NONE																							
Arizona	Four Step	Rural and Urban		1,273	6,412		HBW: 13; HBO: 59; NHB: 30; Long Trips: 2														Urban: 1.05; Rural: 1.20			AZ Statewide Travel Demand Model - Development and Validation Report, May 2009, HDR
Arkansas	NONE																							
California	Hybrid	[illegible]		4,067	100,125	[illegible]	[illegible]						[illegible]	[illegible]				Rural: 0.94; Suburban: 1.11; Urban: 1.14			Rural; Suburban; Urban	Freeway; Expressway; Major Arterial; Minor Arterial; Collector	Purpose, Distance range / residence area type, travel surveys, HH size, HH income range, HH auto-ownership, HH # of workers, party size.	
Colorado	NONE																							
Connecticut	Four Step						[illegible]																____ Model: TRANSEARCH, 1997 Commodity Flows Survey, FAF data, 1970 Conn DOT truck survey, FHWA data.	Conn Truck SWTM Dec-04
Delaware	Four Step		[illegible]	905	10,247	[illegible]	[illegible]																Four-Step Model: mode choice, assignment w/ TRANPLAN Logit Toll Diversion model, peak season model. Uses surveys to gather O-D, travel, and HH data.	
Florida	Four Step		[illegible]	6,000		[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]			CBD = 1.03; Fringe = 1.01; Residential = 1.01; OBD = 0.96; Rural = 1.00; TOTAL = 1.00	[illegible]		CBD; Fringe; Residential; OBD; Rural	Freeway; Divided Arterial; Undivided Arterial; Toll	Employment data: BEBR; Trip Generation: NHTS 2001; Freight Model: VIUS surveys, TRANSEARCH	FSWM ppt Jan-07
Florida (Turnpike)	Synthetic							[illegible]															Uses FDOT traffic count data, land use component, trip matrix estimation (zone-to-zone trip table), Toll modeling (ramp-to-ramp costs for all tolls),	
Georgia	Synthetic						Auto and Origin-Destination Matrix Estimation; Commodity carrying truck; Non-Commercial truck														Rural	Rural: Principal Art - Interstate, Principal Arterial - Other; Min Arterial, Maj Collector, Min Collector, Local; Urban: Principal Art - Interstate, Principal Art - Freeway/Exp	Origin-Destination Matrix Estimator	GDOT-ISP Mar-04
Hawaii	NONE																							
Idaho	Dormant																							
Illinois	Dormant																							
Indiana	Four Step		[illegible]	4,720	34,000	[illegible]	[illegible]	[illegible]				Long Trip IVTT (-0.0069) OVTT (-0.0083)	Fixed shares for short trip purposes; Multinomial logit for long trip purposes; Auto; Bus; Walk; Bike		[illegible]; 8,001 - 10,000 = 35.52; 10,001 - 15,000 = 35.60; 15,001 - 20,000 = 31.33; 20,001 - 25,000 = 29.34; 25,001 - 30,000 = 26.45; 30,001 - 40,000 = 21.93; 40,001 - 50,000 = 15.74; 50,001 - 75,000 = 13.22; 75,001 - 100,000 = 14.60; > 100,001 = 19.87; TOTAL = 39.42				[illegible]; Rural Minor Coll. (23.52); Rural Local Roads (15.96); Urban Interstates (2.4); Urban Freeways (1.36); Urban Principal Art. (-4.68); Urban Minor Art. (6.45); Urban Coll. (0.53); Urban Local Roads (-10.56)		Major Employment District (1.62); Urban (-2.03); Suburban (7.65); Rural (2.55)	2-lane 2-way undivided; 2-lane 2-way divided; Multilane undivided; Multilane divided; Full access controlled highway	Four Step Model: • Trip Productions: Income/Veh. avail., Area Type/HH Size/Veh. avail. • Employment Data: ES-202, productivity factors • AADT, Reebie Data (TRANSEARCH) • Accessibility to: freight, HH, pop, university enrollment, wealth • Includes traffic signals, using lowy database and crash data for placement • Free-flow speed estimation for improved level of accuracy • K-factors borrowed from Kentucky Transportation Cabinet	TRB Study (8/1/2005); NCHRP (4/1/2006); Indiana SWTDM Upgrade (9/2004)
Iowa	Four Step												Passenger Car Model; Truck (Commercial Veh.) Mode; Statewide Rail Freight Mode; Commodity Freight Flow Mode										Three-Step Model: Trip Gen, Trip Dist, Assignment Model, & Truck-sub Model. Identify economic sectors, data requirements & sources. Data Sources: REMI, Woods & Poole, MPO TAZs, FAF2 data for freight.	ISWTDM ppt@ TRB Jan-09 ISU Nov-96
Kansas	[illegible]																							
Kentucky	Four Step		[illegible]	[illegible]	77,272		[illegible]						NONE	LD-Business: 1.80; LD-Tourist: 3.31; LD-Other: 2.4[illegible]								All Arterial Roads and, outside the model MPO's, all collector roads	Three-Step Model: Trip prod & attract, trip dist, assignment, no mode split. Final Ground Adjustment Program (10 Screen Lines), HPMS (outside KY networks), TRANSEARCH, NHTS, AST (long-dist travel), 2000 Census, Woods & Poole, Dun & Bradstreet, Claritas	TRB Study Aug-05 NCHRP Apr-06
Louisiana (Macro) (more than 100 miles)	Four Step		[illegible]	929			[illegible]	[illegible]						Nation / Louisiana; Business: 1.82 / 1.86; Tourist: 3.23 / 3.44; Other: 2.48 / 2.64						2 or less; 3 or more		Rural Interstate, RPA (Full Access Control), RPA (Partial or No Access Control), RMIA, RMaC, RMiC, Local System, Urban Interstate, UArtExway, UOtherPA, UMIA, UC, UL, All Link & Ferry Links, (All arterials and collectors outside the modeled urban areas)	____ Model: Data: TRANSEARCH, 1995 ATS (Long-dist travel), 1990 J-T-W data, HPMS & NHPN (outside LA networks), Woods & Poole, Dun & Bradstreet, Claritas	LA SWTM Sep-04 TRB Study Aug-05
Louisiana (Micro) (less than 100 miles)	Four Step		[illegible]	[illegible]			[illegible]	[illegible]	Short Distance (<100 miles); HBW = 17.3 min / 21%; HBO = 12.2 min / 29%; NHB = 9.3 min / 35%					HBW: 1.1534; HBO: 1.776[illegible]; NHB: 1.7926						2 or less; 3 or more	Urban, Second City, Suburban, Small Town, Rural			LA SWTM Sep-04 TRB Study Aug-05
Maine	Yes																							
Maryland			[illegible]	[illegible]	167,193																			
Massachusetts	Four Step		[illegible]	3,000		[illegible]	[illegible]		Purpose (min): HBW (23.05); HBO (14.57); HBSR (16.19); HBSc (13.93); NHBW (17.91); HBSh (15.06); NHBO (15.62)		Purpose (% Intz): HBW (6.3); HBO (17); HBSh (16.5); HBSR (15.3); HBSc (16.5); NHBW (18.4); NHBO (19.2)							Urban (0.1%); Suburban (-0.2); Rural (-3.8); TOTAL (-0.8)	Freeway (2.5%); Arterials (-11.7); Collectors (-8.8); TOTAL (-0.9)			All Collectors and higher, no local roads	____ Model: Data: NPTS 1995 (Trip Prod), NPTS 2000 emp (Trip Attract). Distribution: gravity model, NPTS data, BPR vol. Delay. Zone Data: 2000 Census, Mass Highway MPO. ES-202 had many errors, searching for better data.	TRB Study, 8/1/2005; Massachusetts Statewide Travel Demand Model Final Report (6/2004)
Michigan	Four Step		[illegible]	[illegible]			[illegible]																Auto trips are based on HH size and income, area type, trip purpose and trip length	MI SWTDM Sep-99
Minnesota																								
Mississippi	Micro Model		[illegible]	[illegible]	171	[illegible]	[illegible]						Passenger and Freight mode	Auto; HBW - 1.10; HBO - 1.55; NHB - 1.56					Interstate (1.00); Major Arterial (0.99); Minor Arterial (1.03); Major Collector (0.88); Minor Collector (0.95); Local (1.13)		Areas inside Mississippi are modeled at a detailed level with aggregated urban TAZs and rural zones following Census tracts. Areas outside Mississippi are modeled at the county level using the National Highway Planning System (NHPS) network. Areas further away from Mississippi use Bureau of Economic Analysis (BEA) zones and Interstate Highways.	Rural - Interstate, Major Arterial, Minor Arterial, Major Collector, Minor Collector, Local; Urban - Interstate, Other Freeways, Other Major Arterial, Minor Arterial, Collector, Local	Data: American Travel Survey, National Household Transportation Survey, U.S. Census, Dun & Bradstreet Demographic Data, Reebie Commodity Flow Data, National Highway Planning Network, FHWA Highway Performance Monitoring System (HPMS), and Mississippi Roadway Characteristic file and traffic count data	Multiplan: The Future in Motion; Mississippi Statewide Model Methodology
Mississippi	Macro Model				274	Long Distance (Intrastate / Interstate) [illegible]	Long Distance (Intrastate / Interstate) [illegible]						Commodity Flow Data	Purpose (Intrastate / Interstate); Business (1.39 / 1.50); Tourist (2.55 / 2.55); Other (2.05 / 2.26)										
Missouri	Four Step																					All arterial and higher, many collector, and some local roadways		TRB Study Aug-05
Montana	Yes																							
Nebraska	Yes																							
Nevada	NONE																							
New Hampshire	ABM					No Freight or long-distance travel	[illegible]															Freeways; Expressways; Arterials; Collectors; Local Roads	____ Model: Data Collected from statewide surveys & data by mode, social, land use, & HH. HH surveys & transit-on-board studies conducted in 1994. 2000 Census, Dun & Bradstreet emp data.	TRB Study Aug-05
New Jersey (Recreational/Non-Recreational)	Four Step		[illegible]				[illegible]						Passenger Model; Auto, Transit; Freight Mode; Heavy truck, Commercial; Recreation Model										Four-Step Model that combined the 3 Jersey Regional models & 2 from NY/NJ Port Authority & New Castle County, DE model. Includes a Life Cycle tabulation. Trip Dist based off emp, HH, special generator and FHWA truck generation data.	TRB Study Aug-05 NJDOT Davis, T.E.
New Mexico	Synthetic						Origin-Destination Matrix Estimation						Passenger model, and Freight model											
New York	NONE																							
North Carolina	NONE																							
North Dakota	NONE																							
Ohio	ABM		[illegible]	5,[illegible]	263,000		[illegible]															All functional class collector and better with some local roads	Focuses on Economics & LU, NOT Four-Steps. S3: O-D comparisons, global assignment checks, detailed assignment validation. Data: 2000 Census, ES-202, TRANSEARCH, County Level VMT.	NCHRP Apr-06 TRB Study
Oklahoma	NONE																							
Oregon	ABM		[illegible]				[illegible]	[illegible]					Passenger: Auto, Pass Rail, Intercity Bus; Freight: Lt Truck, Hvy Truck, Container Freight Rail										Uses LU & Economic factors, not Four-Step Model. I-O matrix derived from monetary values representing the OR economy. Economic flows transferred into transport flows through LU-transport interface. Mode choice is combined with route choice in the assignment stage. Specific areas covered for the model are: data sources, zone system, transport network, I-O network, Employment by sector, HH by sector, and land market data.	TRB Study Aug-05 ODOT Feb-99
Pennsylvania	Four Step						[illegible]				TOTAL = 37.7%				Rural Interstates = 22%; Rural Principal Arterials = 59; Urban Interstates = 23; Urban Other Freeways = 41; Urban Principal Arterials = 69; TOTAL = 51						Rural; Urban	Rural: Interstates, Principal Art, Min Art, Maj Coll, Min Coll, Loc; Urban: Interstates, Principal Art, Min Art, Collectors, Locals	Four-Step Model: Trip Gen (pop/HH, emp/HH), Trip Dist (Avg trip length min & mile, avg speed), Mode Choice (zone-to-zone cost & tt, regional rail, removes transit), Traffic Assignment (incremental capacity-restrained assignment).	PSTDM ppt Jan-07
Rhode Island	Four Step		[illegible]	1,[illegible]	839		[illegible]	[illegible]						HBW (1.12); HBO (1.56); NHB (1.56)					[illegible]		Rural = 1.12; Urban = 1.00	Interstate = 1.04; Principal Arterial = 1.06; Minor Arterial = 0.91; Collector = 1.02	Two Stages: (1) cordon line & cutline (2) detailed link volumes. Both were performed in accordance with the FHWA "Calibration & Adjustment of System Planning Models". Caliper Corporation's census CD for pop. Data, Dunn and Bradstreet emp. data,	Rhode Island Statewide Planning Program Technical Paper: Statewide Travel Model Update (2006)
South Carolina	Operational																							
South Dakota	NONE																							

Legend
Models Reviewed
No Documentation Reviewed
No Model

State	Model Type (as of 2005)					Aggregate Trip Rates	Trip Purposes & %	Average Trip Lengths	Trip Length Frequencies	Coincidence Ratios	Intrazonal Trips	Terminal Times	Mode Split	Auto Occupancy Rates	RMSE	GEH	V-C Ratios by: VMT/VHT	V-C Ratios by: Area Type	V-C Ratios by: Facility Type	V-C Ratios by: Lanes	Area Type	Facility Type	Sources for Calibration	Sources for Model Information
Tennessee	Synthetic		Pop: 5689283 HH: 2439443 Emp: 4445909 Autos: 2232905	1,222 Internal 175 External		HH: 7.5489 DVMT (millions): Person: 104 (2003) 180 (2030)	Origin-Destination Matrix Estimation (3 tables) HBW: 22 HBO: 42 NHB: 36	23.94 Min							0 - 2,500 = 0.272 2,500 - 5,000 = 0.218 5,000 - 10,000 = 0.169 10,000 - 15,000 = 0.353 15,000 - 20,000 = 0.254 20,000 - 30,000 = 0.202 30,000 - 40,000 = 0.182 40,000 - 50,000 = 0.088 50,000+ = 0.061		Model/TRIMS = 0.89			2,4,6	1. Rural 2. Sm. Urban 3. MPO	1. Entire Interstate System 2. All Principal Arterial 3. All Rural Minor Arterials 4. All in TDOT's Major Hwy System	OD Matrix Estimator Model: TRIMS Network Traffic Counts, Network Configuration Changes, Network Attribute Updates Access Link Placement, Seed Trip Table.	TL RTP Dec-05
Tennessee	Yes						OD by Commodity I-I I-E E-E						Truck = 64% Rail = 19% Air = 0% Water = 17%										OD Matrix Estimator, Commodity growth indicators	
Texas (Passenger Model)	Four Step		Pop: 20851820 HH: 8157575 Emp: 15617373 Autos: 7393354	4,600 Internal 142 external	60,500	Special Generator Rate A University Hospital Military Hotel / Retail	Daily Trips: HBW (16), HNW (49), NHB (31), OTH (4) Period Trips (75+ miles): WORK (1), NWR (26) External Local: EXTLong, EXTShort External Through: EXTR	HBW (16), HBNW (9.06), NHB (9.68), OTH (10.83), WORK (200.82), NWR (199.71), EXTS (30), EXTL (125.76)		Work: 0.915215 Non-Work: 0.927021			Passenger Model Trip Generation Trip Distribution Mode Choice Traffic Assignment	WORK = 1.33 NWR = 2.06	0-1,000 = 290 1,000 - 2,500 = 116 2,500 - 5,000 = 90 5,000 - 10,000 = 70 10,000 - 25,000 = 61 25,000+ = 40 TOTAL = 50		Observed: 96,326,859 Unadjusted: 96,301,962 Adjusted: 97,015,121 (1% difference)		Interstate: 0.74 US Highway: 1.07 State Highway: 0.61 Farm to Market/Ranch: 0.21 TOTAL: 0.82		Urban and Rural CBD, Suburban, Large Urban, Small Urban Urban Central, Rural East, West and Panhandle Counties with MPO, Counties without MPO Just Partially in MPO (for Pop. Data)		OD Surveys Woods and Poole Emp. Data, JTW Data NPTS, ATS, CTPP	Texas Statewide Analysis Model Theory Report, SAM Refinements & Revalidation for I-69/TTC Tier 1 EIS
Texas (Freight Model)	Four Step						Commodity Groups: Food, Textiles, Wood, Building Materials, Chemicals/Petroleum, Machinery, Secondary I-I, I-E, E-I, E-E	Food (218), Textiles (273), Wood (227), Building Mat. Chemicals/Petrol (202) Machinery (196), Secondary (201)					Freight mode Trip Generation Trip Distribution Mode Choice Traffic Assignment										OD Surveys Reebie TRANSEARCH.	Texas Statewide Analysis Model Theory Report (3/10/04), SAM Refinements & Revalidation for I-69/TTC Tier 1 EIS (1/2006)
Utah (Passenger Model)	Four Step	Rural and MPO	Pop: 2233169 HH: 768594 Emp: 1600279 Autos: 701281	3,220 Internal 27 external	26,000	HBW: 1.38 HBO: 4.03 NHB: 3.44 HBW - Long: 0.03 HBO - Long: 0.05 Total: 8.94	HBW (15.6) HBO (45.1) NHB (38.6) Work - Long (0.3) Non-Work - Long (0.6)	HBW: 17.95min HBO: 12.98 NHB: 12.37 HBW - Long: 89.54 HBO - Long: 81.73 EI - Business: 51.26 EI - Other: 55.49			HBW (5.6%) HBO (6.5) NHB (8.3)		Passenger Model		500 = 147 1,500 = 91 2,500 = 97 3,500 = 74 4,500 = 59 5,500 = 57 7,000 = 53 8,500 = 57 10,000 = 76 12,500 = 81 15,000 = 47 17,500 = 34 20,000 = 51 25,000 = 45 35,000 = 36 55,000 = 36 75,000 = 41 999,999 = 18 TOTAL = 49		Statewide: 13,474,200					Freeway Arterial Collector Rural & Mountain Road	Trip Distribution uses Gravity Model Approach	Utah Statewide Travel Model: Draft Model Validation (May 18, 2009)
Utah (Freight Model)	Preliminary						Commercial Single Unit Multi Unit Inbound (Ext) Outbound (Ext) Through (Ext)	Miles Commercial: 22.3 Single Unit: 27.5 Multi Unit: 28.29					Freight Model				Commercial: 1,833,642 Single Unit: ... Multi Unit: ... Combined Unit: ... All Links: 98,594,431 (Total VMT)							Utah Statewide Travel Model: Draft Model Validation (May 18, 2009)
Vermont	Yes	Rural and Urban	Pop: 608,827 HH: 294,382 Emp: 317,817 Autos: 421,906	698	12,439		HBW: 23.3 HBShop: 12.8 HBSchool: 5.8 HBO: 32.2 NHB: 25.8	HBW: 21.79 HBShop: 20.78 HBSchool: 19.24 HBO: 18.56 NHB: 14.49 Truck: 28.62 NHB/Truck Avg: 17.51			HBW: 5.0 HBShop: 5.3 HBSchool: 11.3 HBO: 9.0 NHB: 14.3 Truck: 4.9 Total: 8.5							Urban: 1.07 Rural: 0.94	Interstate: 0.96 Principal Arterial: 1.02 Minor Arterial: 0.96 Major Collector: 0.93 Minor Collector: 1.02 Collector: 1.11		Urban Rural	Interstate Principal Arterial Minor Arterial Major Collector Minor Collector Collector		Vermont Statewide Travel Demand Model Improvements – Updated Passenger & Truck Models in CUBE/Voyager (June 2007)
Virginia (Macro)	Four Step						Long-distance: Business: 16.60 PBusiness: 30.75 Tourist: 52.65	minutes / mile 127.13 / 138 124.58 / 135 126.67 / 137 minutes	Long-distance Intrastate: 3% Long-distance Interstate: 24 Truck - Vehicle: 15				Passenger Model: auto and rail	Long-distance: Business: 1.82 Tourist & Other: 2.65			LD - Interstate = 89% LD - Lt Interstate = 74% SD - HBW = 36% SD - HBO = 36% SD - NHB = 37% TOTAL LD = 13% TOTAL SD = 36% TOTAL = 42%	Not in MSA = -3% <250K = 12% 250-499K = 5% 500-1M = -1% 1-3M = 11% >3M = 30%	Interstate = 1% Major Arterial = 2% Minor Arterial = 16%		Rural Urban Other	Rural Interstate, Rural Principal Arterial Rural Min Arterial, Rural Maj Collector Rural Min Collector, Rural Local Urban Interstate, Urban Freeway & Expressway, Urban Other Principal Arterial, Urban Min Arterial Urban Collector, Urban Local Centroid Connector, Ramp, Parkway Toll Road, Ferry	______ Model: Skip Trip Gen & Dist, instead focuses on creating more accurate trip tables using existing data sources, to avoid having to gather data. Data Sources: Zonal Geo (BEA, 2000 Census MPO zones), Networks (NHPN, FHWA HPMS data), Demographics (Census, PUMS (HH), VA Dept of Labor), Trip Gen (1995 ATS, 2000 Census), Prod (2001 NHTS), Attract (NCHRP Report 365), Freight (TRANSEARCH), Emp (Dun & Bradstreet).	TRB Study Aug-05 VSTM Jan-05
Virginia (Micro)	Four Step		Pop: 7078515 HH: 2904192 Emp: 5629980 Autos: 2699173	1,582	245,935	Short-distance: Trips person / HH HBW: 0.53 / 1.38 HBO: 1.96 / 5.14 NHB: 1.14 / 2.98 Total: 3.62 / 9.50	Short-distance: HBW: 14.54 HBO: 54.09 NHB: 31.37	minutes HBW: 14.6 HOB: 10.8 NHB: 23.17	Short-distance HBW: 31% Short-distance HBO: 21 Short-distance NHB: 5 Truck - Vehicle: 15				Freight Model: by commodity for truck, rail, air, and water cargo				LD - Interstate = 89% LD - Lt Interstate = 74% SD - HBW = 36% SD - HBO = 36% SD - NHB = 37% TOTAL LD = 13% TOTAL SD = 36% TOTAL = 42%	Not in MSA = -3% <250K = 12% 250-499K = 5% 500-1M = -1% 1-3M = 11% >3M = 30%	Interstate = 1% Major Arterial = 2% Minor Arterial = 16%		Rural Urban Other			TRB Study Aug-05 VSTM Jan-05
Washington (Model Never Completed, 2005)	NONE: Benefit Evaluation System																							TRB Study Aug-05
West Virginia	NONE																							
Wisconsin (Passenger Model)	Yes	Statewide shows urban areas at higher detail than rural areas, but less detail than MPO models.	Pop: 5363675 HH: 2321144 Emp: 4157030 Autos: 2084544	1,875	200,000	10.33 per HH HBW: 17.3 HBO: 5.75 NHB: 2.86 Business: -0.02 PBusiness: -0.01 Leisure: -0.05	HBW: 17 HBO: 55 NHB: 28 Long Distance (One-way trips > 50 miles) Business = 23.15 Personal Business = 15.47 Leisure = 61.38	HBW = 16.14 HBSh = 16.03 HBSR = 18.09 HBSc = 13.83 HBO = 13.91 NHB = 12.74	67% (Socia) to 85% (NHB)		HBW = 29.2% HBSh = 41.0 HBSR = 37.4 HBSC = 51.5 HBO = 53.6 NHB = 54.4		Passenger Model Daily recurring travel, Long-distance Intercity Transit		0-1,000 = 80.61 1,001 - 2,500 = 62.33 2,501 - 5,000 = 41.82 5,001 - 10,000 = 32.00 10,001 - 20,000 = 22.30 20,001 - 30,000 = 19.33 30,001 - 40,000 = 13.62 40,001 - 50,000 = 13.91 TOTAL = 39.21						Rural Suburban Dense Urban	Interstates, Freeways, Expressways, Principal Arterials, Minor Arterials, Major Collectors Collectors, Local Roads, Ramps	Four-Step Model. Data Sources: 2000 Census (CTPP), WisDOT user counts, Validation Manual & NCHRP Report 365, FHWA (1997 SWM Handbook), compare model results to NHTS, compare district-to-district flows, TRANSEARCH	NCHRP Apr-06 Wis SWM ppt Sep-06 TRB Study Aug-05
Wisconsin (Freight Model)	Yes												Freight Mode Commodity flow approach – OD 25 commodity groups were used			0-5 = 27% 5-10 = 16 10-20 = 28 20-40 = 29 > 40 = 1					Rural Urban	Rural: Interstate, other PA Urban: Interstate, Freeway, Expwy, other P.		
Wyoming	NONE																							