Transportation Planning and Technology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gtpt20

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Chenfeng Xiong & Lei Zhang
Department of Civil and Environmental Engineering, University of Maryland, 1173 Glenn Martin Hall, College Park, MD, 20742, USA
Published online: 15 Mar 2013.

To cite this article: Chenfeng Xiong & Lei Zhang (2013) Deciding whether and how to improve statewide travel demand models based on transportation planning application needs, Transportation Planning and Technology, 36:3, 244-266, DOI: 10.1080/03081060.2013.779473
To link to this article: http://dx.doi.org/10.1080/03081060.2013.779473

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Deciding whether and how to improve statewide travel demand models based on transportation planning application needs

Chenfeng Xiong and Lei Zhang*

Department of Civil and Environmental Engineering, University of Maryland, 1173 Glenn Martin Hall, College Park, MD 20742, USA

(Received 11 February 2011; accepted 10 October 2012)

Many states in the USA have developed statewide travel demand models for transportation planning at the state level and along intercity corridors. Travel demand models at mega-region and provincial levels are also widely used in Europe and Asia. With modern transportation planning applications requiring enhanced model capabilities, many states are considering improving their four-step statewide demand models. This paper synthesizes representative statewide models developed with traditional four-step, advanced four-step, and integrated micro-simulation methods. The focus of this synthesis study is as much on model applications and data requirements as on modeling methods. An incremental model improvement approach toward advanced statewide models is recommended. Review findings also suggest model improvement activities should be justified by planning application needs. For statewide model improvement plans to be successful and financially sustainable, the return on model improvement investment needs to be demonstrated by timely applications that rely on improved model capabilities.

Keywords: transportation planning; travel demand models; model applications; data requirements; model improvements

1. Introduction

In comparison to traditional metropolitan transportation planning models that only focus on one specific urban area, in the US statewide models consider multimodal person and freight travel in all areas within a State and long-distance trips crossing State borders. Nowadays, around 30 states in the USA have developed operational statewide transportation models with varying degrees of sophistication, and several other states are in the process of developing their own statewide transportation models.

Various studies (cf. Souleyrette, Hans, and Pathak 1996; Giaimo and Schiffer 2005; Horowitz 2006, Cohen et al. 2008; Horowitz 2008) have documented the development of current statewide models. For example, Zhang et al. (2012) reviewed several methodologies for multimodal inter-regional travel demand modeling, also drawing examples from both statewide applications within the USA and from national models that are of the similar scale to a typical statewide model. These studies give a snapshot of the state-of-the-art practice and highlight innovative efforts by a few states/nations.
According to the literature and the authors’ synthesis, statewide models may be categorized into three groups for the review analysis in this paper: traditional four-step models, advanced four-step models, and integrated land use/economic and activity-based microsimulation models. This paper provides a graphical illustration of the status of US statewide travel demand models in Figure 1.

Most states have adopted the basic four-step demand modeling approach. A few statewide transportation models have incorporated advanced model features such as discrete choice methods, multimodal freight analysis modules, tour/activity-based microsimulation approaches, and land use/economic integrated modeling frameworks. Quite a few states have started programs aimed at improving their statewide models, including not only those with basic four-step models (e.g., Michigan and Texas) but also those with advanced modeling components such as California and Florida among others, from which a broad interest toward more sophisticated modeling techniques with higher policy analysis and planning capabilities can be easily perceived.

How and to what extent in the next step should a specific statewide model be enhanced? The purpose of this paper is not to conduct another comprehensive review of statewide travel modeling practices but to provide insights into model improvement strategies and supplement the aforementioned reviews in several ways. First, the paper focuses on three aspects of statewide travel models including methodology, data, and applications, which help identify the different capabilities and data needs of different modeling techniques. Second, the discussion on statewide travel models in this paper is organized into three sections (traditional four-step, advanced four-step, and activity-based/microsimulation approaches) based on modeling methodology. This should help decision-makers and modeling developers evaluate different options.

![Figure 1. Status of statewide travel demand models in the USA.](image-url)
for creating or improving their statewide travel demand models. Third, different from previous reviews that are comprehensive but offer little in-depth information on individual statewide models, this paper describes selected representative statewide models in greater depth. Finally, this paper summarizes representative applications of statewide models at different levels of sophistication.

Each of the following three sections (Sections 2, 3, and 4) discusses representative statewide models according to the three model groups, respectively, with a focus on their application capabilities. Table 1 provides an overview of the statewide models that are selected for our in-depth review. Section 5 provides observations on statewide transportation model improvement plans and activities in several states. Section 6 concludes the paper and makes recommendations on whether and how to improve statewide transportation models.

2. Traditional four-step models

The traditional four-step approach seen in many metropolitan planning organization (MPO) models and national-level models is also the most dominant methodology for statewide analysis. Most of these models share the following characteristics: their passenger models are constructed from existing MPO models and national travel surveys (e.g. Massachusetts and Missouri); in some cases (e.g. New Jersey), the statewide model is built entirely from the MPO models; the freight analysis methods range from growth factor methods (e.g. Kentucky and Oklahoma, see Cohen, Horowitz, and Pendyala 2008), to non-commodity-based approaches using quick response techniques (e.g. Massachusetts and New Jersey, see Beagan, Fischer, and Kuppam 2007), and to commodity-based approaches based on national and commercial freight databases (e.g. Freight Analysis Framework, TRANSEARCH).

2.1. Model structure

This approach is defined by its well-known four sequential stages. The demand modeling process is aggregate and trip-based with limited behavioral analysis. Time-of-day choices are not considered. Statewide models that fall into this category include Indiana, Maryland, Massachusetts, Michigan, New Jersey, Tennessee, Virginia, Wisconsin, and others. Many of these states have been looking into the enhancement possibilities, such as Indiana, Michigan, and Maryland (Giaimo and Schiffer 2005; Ottensmann et al. 2009).

The New Jersey Statewide Model is an interesting case. Three MPO models and two cross-border regional models have been directly combined. All the sub-models are basic four-step models. If most of the areas and/or population in a State are within MPO boundaries, this approach can be quite effective and save cost and time. One challenge is to ensure consistency among all sub-models, especially along sub-model boundaries. In the development of the New Jersey Model, the ‘trip table weaving’ technique has been used extensively to address this issue. For trips in each MPO model with at least one end in external zones, their origin-destination (OD) tables at different time scales are ‘woven’ between relevant MPO models. After trips crossing MPO boundaries are distributed from one model to its connecting model, the total number of external trips is then balanced to ensure consistency.
<table>
<thead>
<tr>
<th>State (model name)</th>
<th>Design period</th>
<th>Data sources</th>
<th>Modes considered</th>
<th>Purposes considered</th>
<th>Zone structure</th>
<th>Model description</th>
</tr>
</thead>
<tbody>
<tr>
<td>California (HSR Interregional Model)</td>
<td>2006</td>
<td>The 2000–2001 Statewide Household Travel Survey, urban area travel surveys, onboard interview</td>
<td>Air, conventional rail, High-Speed Rail, and car</td>
<td>Business, commute, recreation, and other</td>
<td>4667 zones, disaggregated from the previous Caltrans model’s zone system. Using complete discrete choice methods in all the sub-models. Using nested-logit models in the mode choice and access/egress mode choice sub-models. The model will be integrated with land use and economic model.</td>
<td></td>
</tr>
<tr>
<td>Florida (FISHFM Freight Model)</td>
<td>Late 1990s to 2002</td>
<td>TRANSEARCH freight database</td>
<td>Truck, carload rail, intermodal rail, water, and air</td>
<td>14 commodity groups (agricultural products, minerals, coal, food, non-durable manufacturing, lumber, chemicals, paper, petroleum products, other durable manufacturing, clay/concrete/glass/stone, waste, miscellaneous freight, and warehousing)</td>
<td>Originally it has 508 internal zones and 32 external zones. It has been upgraded to 3974 zones by an on-going study.</td>
<td>Commodity-based multimodal four-step freight model</td>
</tr>
<tr>
<td>Indiana</td>
<td>Mid 1990s, updated in 2004</td>
<td>Indiana statewide household travel survey</td>
<td>Auto, truck, and transit</td>
<td>Home-based work, home-based other, other business, non-home based, recreational</td>
<td>Previously 500 internal and 50–60 external, which was upgraded to 4720 zones in 2004</td>
<td>Conventional four-step model. In 2004, a land use module has been incorporated</td>
</tr>
<tr>
<td>State (model name)</td>
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<tr>
<td>Massachusetts</td>
<td>2000–2004</td>
<td>1995 National Personal Travel Survey (Massachusetts oversample), and ES-202 employment data</td>
<td>Multiple passenger modes</td>
<td>Business, private, and vacation</td>
<td>3500 internal zones, 99 external stations, and 155 ‘park-n-ride’ centroids</td>
<td>Conventional four-step model, with feedback loop between the first and the fourth steps</td>
</tr>
<tr>
<td>Michigan</td>
<td>Mid 1990s</td>
<td>Household-based travel surveys; Border-crossing interviews; Road traffic counts</td>
<td>Auto only</td>
<td>Home-based work, home-based social recreation vacation, home-based other, non-home-based work, non-home-based other</td>
<td>2307 internal TAZs and 85 external TAZs</td>
<td>Conventional four-step model. Currently, MDOT is developing a more advanced tour-based model using a recently collected statewide survey data</td>
</tr>
<tr>
<td>New Hampshire (NHSTMS)</td>
<td>1994–1995</td>
<td>New Hampshire Activities and Travel Survey, transit on-board surveys, roadside intercept surveys</td>
<td>Non-auto, drive alone, carpool, auto access to transit, and truck</td>
<td>Work, school, shopping, recreation, chauffeuring, and other</td>
<td>About 500 zones, 1 zone per 5000 population</td>
<td>Tour-based four-step model, with time-of-day sub-model</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Late 1990s</td>
<td>Three MPO models and two additional urban models</td>
<td>Multiple passenger modes, Only truck mode in freight</td>
<td>Integrating purposes considered in those MPO models</td>
<td>2762 internal zones and 51 external zones</td>
<td>Using model weaving technique to combine its three MPO models and two regional models</td>
</tr>
<tr>
<td>State (model name)</td>
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<tr>
<td>Ohio</td>
<td>Since mid 1990s</td>
<td>Socioeconomic data (U.S. Census, County Business Patterns, ES-202, etc.), statewide household travel survey, long-distance travel survey, roadside interviews, traffic counts, land use/value data, etc.</td>
<td>Auto, air, walk to transit, drive to transit, multiple freight modes</td>
<td>Home, work (no work-based subtour), work (with work-based subtour), school, shop, recreation, and other. For long distance, the purposes include: household, work-related, and other</td>
<td>Nested zone structure, with 700 activity model zones, 5103 TAZs, and grid cells within each TAZ</td>
<td>Using activity-based approach, integrated with land use and economic modules. A simpler interim model is currently operational</td>
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<tr>
<td>Oregon (TLUMIP Model)</td>
<td>Since 1996</td>
<td>Household activities and travel survey, Oregon travel behavior survey, recreation/tourism activity survey, longitudinal panel survey. For freight, commodity flow data, freight shipper and carrier survey data, and truck intercept survey data were collected</td>
<td>Auto, transit, multiple freight modes</td>
<td>Home-based work, work-related, recreation, home-based other, non-home-based other. For long distance, the purposes include: entire household, non-regular person work commute, and other. 42 commodity groups were clarified in the freight module of the second generation model</td>
<td>125 zones in the 1st generation model, which was upgraded into a nested zone structure, with 2950 alpha-zones and 519 more aggregated beta-zones</td>
<td>Using activity-based approach, integrated with land use and economic modules. A simpler transitional model is currently operational</td>
</tr>
<tr>
<td>State (model name)</td>
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<tr>
<td>Virginia</td>
<td>1995-2000</td>
<td>Census 2000, PUMS, 1995 American Travel Survey, 2000 Census Transportation Planning Package, 2001 National Household Travel Survey</td>
<td>Auto, rail, bus and other</td>
<td>Home-based work, home-based other, and non-home based</td>
<td>Macro zone system (522 zones) and micro zone system (1059 zones)</td>
<td>Conventional four-step model. Recently, VDOT has evaluated the feasibility of activity-based approach in Virginia, and decided to maintain the basic methodology.</td>
</tr>
</tbody>
</table>
In these statewide models, the freight modules usually employ relatively simple methodologies. For instance, Louisiana, Oklahoma, and Kentucky all employ the OD Factoring Method wherein growth factors based on economic, employment, and other growth indicators are applied to existing data such as the TRANSEARCH. Other states with more closely spaced or contiguous urban areas such as New Jersey and Massachusetts (Cohen, Horowitz, and Pendyala 2008) have employed truck models without considering the modal split. All truck trips are usually classified into light, medium, and heavy truck trips, and then assigned simultaneously with passenger trips.

2.2. Data
In general, this approach does not require dedicated data collection efforts, while national data sources are commonly used with oversampling at the state level (e.g. Massachusetts). The available national data-sets include the decennial Census Transportation Planning Package (CTPP), the American Travel Survey (ATS) in 1995, the Nationwide Personal Transportation Survey (NPTS) in 1995, and the National Household Travel Survey (NHTS) in 2001. Indiana is an exception, which conducted its own household travel survey in 1995.

In addition, sub-state level data-sets initially collected for regional and MPO modeling have also been used. For instance, the New Jersey model relies on the sub-state Regional Travel Household Interview Survey (RT-HIS) collected in 1997 and the Comprehensive Total Travel Survey (CTTS) in 1989. Traffic count data have been routinely used for calibration/validation. In the development of the trucking freight module for the Virginia statewide model, traffic counts classified by vehicle types were used to estimate truck OD demand.

2.3. Applications
This type of statewide model has relatively limited applications with less behavioral sensitivity requirement which mainly lie in corridor-level transportation planning and performance measurement, freight analysis, congestion management, and sub-area studies.

Corridor planning has been one of the major application areas. For instance, the Virginia model has proven valuable in analyzing trucking commodity flows along the I-81 interstate corridor. It has been applied to estimate heavy truck percentages at various locations, differentiate local and through truck traffic, and identify truck travel patterns. It has also been applied to estimate automobile traffic in rural areas and to analyze intercity passenger rail. In Indiana, outputs from the statewide model were used to develop a sub-state demand model for the I-69 corridor (Bernardin, Lochmueller, and Associates Inc. 2006). It was subsequently used to analyze the environmental and economic impact of the highway corridor, e.g. the I-69 Evansville to Indianapolis Tier 2 Environmental Impact Statement (EIS) study.

The New Jersey model has been employed to analyze and improve the I-78 corridor truck traffic conditions. It has also played a crucial role in the New Jersey Congestion Management System, by evaluating various transportation improvement strategies such as High Occupancy Vehicle (HOV) lanes, congestion pricing, arterial signal systems, and other intelligent transportation systems (Davis 1998), which are important components of its five-year transportation improvement plan.
3. Advanced four-step models

These models have incorporated advanced features that significantly improve the capability and reliability for certain applications. But they still loosely follow the four-step procedure, and do not represent a major shift in the behavioral modeling paradigm. Advanced four-step models discussed herein are usually developed independently from the MPO models, except for Florida.

3.1. Characteristics of advanced four-step models

In this category, traditional modeling stages often have been replaced by discrete choice models that are capable to be nested and modeled jointly. The trip-based structure may be enhanced with tour-based methods that recognize trip chaining and choice interdependencies. Several states have also developed advanced freight models that consider multimodal commodity flow types. Other features include vehicle ownership modules, advanced traffic assignment, and time-of-day choices, which are not discussed in detail in this review.

3.1.1. Advanced discrete-choice models

Rather than considering trips at the traffic analysis zone (TAZ) level, discrete choice models, especially advanced ones that allow flexible error-correlation structures among alternatives, can better represent choices available to individuals. These methods have been increasingly applied for the development of destination choice and trip frequency analysis (TRB 2007).

An interesting example is the California Bay Area Interregional Model, which was developed for high-speed rail (HSR) analysis. It has adopted a model structure completely based on discrete choice methods, as illustrated in Figure 2. The trip frequency and destination choice modules employ multinomial logit models for four purposes: business, commute, recreation, and other. The main mode choice module and the access/egress mode choice modules wherein travelers select ground transportation modes for accessing/egressing air and rail terminals are based on a nested logit model.

3.1.2. Tour-based model

Compared to trip-based models, tour-based models recognize that multiple trips that form a complete tour (e.g. home to work to shopping and back to home) are interdependent due to scheduling, mode choice, travel companion, and other constraints. The New Hampshire Statewide Travel Model System (NHSTMS) was one of the first statewide models that adopted tour-based components within the four-step framework.

The tour-based model structure evolves from the four-step framework (Cambridge Systematics, Inc. 1998). The major difference is that OD tables are produced with tour-based analysis. Following a vehicle availability module, the tour generation stage predicts the number of tours. Additional characteristics of the tours are then generated, such as the number and purposes of intermediate stops. The destination-choice module is divided into two stages with the first one using a multinomial logit
model to predict the primary destination and the second then determining secondary destinations on the tour also with a discrete choice model. Similarly, the mode choice module also has a two-stage design. In Stage 1, a tour-level binomial logit model determines whether or not the tour involves household vehicles. In Stage 2, trip-level multinomial logit models predict other modes used in the tour-based on trip-based stated-preference survey and transit onboard survey data.

The NHSTMS also incorporates a time-of-day module which assumes a set of time-of-day factors for each trip purpose and converts daily trips to am peak, midday, pm peak, and off-peak trips. This is similar to the traditional four-step model. But it also supports trip time choice analysis and dynamic traffic assignment, modeling peak periods to better simulate actual network conditions and associated travel delays. This capability is important for congestion management studies at the corridor or sub-network levels.

### 3.1.3. Commodity-based multimodal freight analysis models

Compared to trucking models, commodity-based freight models advance their capability in forecast mode share using commodity flow data and utility-maximization methods. In more advanced cases, discrete mode choice models are developed, which
are often based on incremental logit and similar pivot-point method that estimate future mode shares based on existing ones. The other three steps in the multimodal freight models usually remain unchanged from trucking-only models. Several states have employed commodity-based freight modules, including Florida, Indiana, Vermont, and Wisconsin (Vermont DOT 2001; Cambridge Systematics, Inc. 2005; Proussaloglou et al. 2007).

The recent development of the Florida Intermodal Statewide Highway Freight Model (FISHFM) is a good example of improving a statewide model with a multimodal commodity-based four-step freight model (Cambridge Systematics Inc. 2002), as shown in Figure 3. FISHFM has been integrated with the statewide four-step passenger travel model to support the implementation of the Florida Statewide Intermodal Systems Plan. The main purpose of the FISHFM is to provide important freight travel forecasts and help Florida DOT serve the market of interregional freight and drayage movement to and from intermodal terminals (Washburn and Ko 2007).

A linear regression model and a conventional gravity model are used for freight trip generation and distribution, respectively. An incremental logit model forecasts the mode share for each commodity type among five alternatives (truck, carload rail, intermodal rail, water, and air). This model pivots mode share estimates from base mode shares in the most recent TRANSEARCH database. Although the Florida statewide model considers multimodal demand, it only assigns truck traffic. This is common because the network information for other modes is often lacking. No State has reported statewide models that are able to handle intermodal freight at the network level (Cohen, Horowitz, and Pendyala 2008).

3.2. Data
As expected, advanced four-step models demand more data. However, data-sets that support the development of traditional approach may also be used. Depending on the design and purpose of the advanced models, it may be necessary to obtain supplemental data in some cases.

In the case of the California model, the primary data source is the activity-based California Statewide Travel Survey, conducted in 2000–2001 for weekday travel (Caltrans 2003) and a total of 17,040 households. Three urban-area household travel surveys are supplemented, which cover major MPOs served by the proposed HSR. In addition, a set of passenger intercept surveys with both revealed preference (RP) and stated preference (SP) components were conducted. The RP survey focused on the status of the latest modes for intercity travel. The SP survey obtained the respondents’ preference for the non-existing HSR mode. Air and some rail passenger surveys were conducted either at the airport/station or on board. The socioeconomic data were obtained from urban models, previous Caltrans statewide models, and the US Census Bureau.

For tour-based models, household activity-travel surveys are often required. The NHSTMS was developed from the one-day New Hampshire Activities and Travel Survey, conducted In 1994/1995. The survey covered 2844 households. A series of transit on-board surveys and a cross-border vehicle intercept survey were also conducted to provide information on transit trips and external trips. In addition, for
An NHSTMS model applications, an SP survey was conducted to test the potential statewide impact of upcoming transportation system and policy changes.

For multimodal commodity-based freight models, commodity-flow data by freight mode and commodity type are necessary. In general, a commodity flow survey (CFS), either from public-sector (e.g. Census Bureau’s CFS) or commercially...
available private-sector sources (e.g. the TRANSEARCH data) can meet these data needs. The commercial data usually have more detailed zone structures (e.g. county-level). The Oak Ridge National Laboratory completed the freight data integration work for Florida (Xiong et al. 2007). Florida purchased the TRANSEARCH database as the primary FISHFM data source that represents existing freight flow patterns at county level. In addition, socioeconomic data including population and employment information has been also employed as input to the trip generation. The data sources include Regional Economic Information System (employment by Standard Industrial Classification, or SIC), Florida Population Studies, County Business Patterns, etc.

As part of the FISHFM model development process, information regarding the location and activities (i.e. base-year and forecast-year ton shipments) of intermodal terminals was also gathered from the National Transportation Atlas Databases for the US and Florida (Xiong et al. 2007) and from intermodal terminal inventories managed by the various modal administrations in Florida. In terms of validation data, truck counts from the Florida AADT Report Series and Truck Weight Study Data for the USA were used.

3.3. Applications

One of the major applications of the California Statewide Model was to support the evaluation of proposed HSR systems. The model has been used to evaluate HSR ridership and revenue for different planning years and under various scenarios including alternative alignments, service frequencies, station locations, operational plans, fare policies, and operating costs.

The NHSTMS was developed to address various planning and policy needs (Sharma, Lyford, and Rossi 1998; Giaimo and Schiffer 2005). Applications include highway project impact analysis, air quality analysis, and studies of policy alternatives such as increasing tolls and transit fares. As stated by the New Hampshire DOT, the NHSTMS would serve as an important tool that integrates congestion management, public transportation, and intermodal management system analysis. However, the lack of financial resources and well-trained staff has limited its applications. Consequently, it has been primarily used for corridor-level transportation studies, and its capabilities in other types of statewide and sub-state analysis have not been fully utilized. For instance, the model was used to estimate transit ridership and HOV lane usage for the I-93 corridor. Another application was the impact analysis of adding additional transit services along the State Route 16 corridor, as a part of the Corridor Preservation Program. More recently, the model was used for policy analysis in a tolling and capacity study along the I-93 corridor.

The integrated passenger and freight model in Florida was applied in various statewide long-run and mid-run transportation planning studies and corridor analyses. Its commodity-based multimodal freight module provided inputs for Freight Movements Analysis and Freight Mode Shift Impact Analysis. One of the most important applications is in the implementation of the Florida Strategic Intermodal System (SIS) Plan, which is a plan for a statewide multimodal transportation system consisting of high-priority facilities including rail corridors, highways, waterways, and intermodal terminals (FDOT 2010). This plan aims at enhancing Florida’s economic competitiveness by addressing various transportation
and economy-related issues. The statewide model has enabled an effective evaluation process for the SIS and each of its modal components (Hancock 2008).

4. Integrated transportation land use-economic-microsimulation models

The most advanced statewide models depart from four-step models with integrated land use-economic-transport analysis and tour/activity-based microsimulation. They have been referred to as the ‘O-Models’ by Giaimo and Schiffer (2005) where ‘O’ stands for omnipotence and also for Oregon and Ohio, the two states that have developed the most innovative statewide models of land use allocation, economic redistribution, and travel. These models attempt to account for all aspects of travel demand at a behavioral level using activity-based microsimulation (Giaimo and Schiffer 2005; Horowitz 2008). They are also characterized by the use of large amounts of purposely collected data, long development time, and high cost.

4.1. Model structure

In terms of the model structure, the Ohio and Oregon models have many similarities. They have fully adopted the philosophy that travel is a consequence of diverse human and economic activities and therefore, should be modeled from activity-based microsimulation. They have both integrated land use and economic components with their models. The details of these two statewide models are documented below.

4.1.1. Ohio

The Ohio model was designed as a combination of various economic, demographic, land use, and transportation components, with close interactions. The integrated model structure is shown in Figure 4. The prerequisites for the travel demand models are the land development and economic activity allocation models, which are built on Production Exchange and Consumption Allocation System (PECAS), a land use model developed by Hunt and Abraham (2005). The PECAS model employs supply/demand equilibrium analysis throughout Ohio to locate economic activities and labor forces, which is based on a nested logit approach.

The Ohio statewide model simulated the household activity-travel decisions, which have two main steps: household synthesis using a TAZ-level Monte Carlo simulation, and personal travel tours dealing with short-distance home-based, long-distance home-based, commercial work-based, and visitor tours separately (Costinett and Stryker 2007). Figure 5 shows the flowchart of the short-distance home-based travel component. Microsimulation techniques are used in each to determine household activity patterns, a list of tours made by the household, and the intermediate trips/stops within each tour (Erhardt et al. 2007). For post-processing, air pollution emissions and accident impact models have been established, as well as a traffic microsimulation model for small portions of the statewide network.

4.1.2. Oregon

The travel demand component of the Oregon2 model is an activity-based microsimulation model with one-year time increments (Hunt et al. 2001). The
Oregon2 modules include regional economics and demographics (ED), production allocations and interactions (PI), household allocations (HA), land development (LD), commercial transport (CT), person travel (PT), and transport supply (TS). The outputs from the seven modules provide the inputs to the data store of the Oregon2 model, which are then used for the next model iteration.

Figure 6 presents the model flowchart, as well as that of a transitional model. The Oregon2 Transitional Model is the current operational model, which was built on the successful application of the first generation. It is not as ambitious, and adopts microsimulation techniques only in the PT module and partially in the CT module. LD and population characteristics are modeled aggregates. The modular design allows advanced components in the Transitional Model to be used in the full Oregon2 model.

Two stages are shown on the left side in Figure 6. The top half of the model simulates the spatial activities, which starts with the ED module adopting an econometric model with simultaneous linear equations to estimate the total economic activities that are then allocated to spatial analysis zones with land use...
development allocated in the ALD module and industrial activities allocated in the PI module. These allocation modules are based on a spatial input-output analysis. The synthetic population generator (SPG) module synthesizes a population that is consistent with the employment totals. Households and jobs are allocated to zones, which is consistent with the PI labor flow results.

The lower half of the model simulates personal and commercial travel. The Transitional Model employs tour-based microsimulation of PT and CT, and simple truck model of external freight travel (ET). The PT module simulates daily travel for nearly six million people generated by the SPG. The CT module translates daily merchandise flow generated in the PI module into truck trips. The TS module employs the EMME/2 equilibrium approach.

Figure 5. Flowchart of the short-distance home-based travel model. Source: Picado et al. 2007.

Figure 6. Difference between the Oregon2 Model and the Transitional Model. Source: Weidner 2005.
4.2. Data

The development of these most advanced models requires significant data collection efforts. For instance, the Ohio model has an extensive list of demand-side data requirements:

- Socioeconomic data (US Census, County Business Patterns, ES-202, and BEA Regional Economic Information System Program);
- Land use data from Department of Natural Resources and County Auditors;
- Land value data from county assessor;
- IMPLAN I/O data used for the aggregate demographic modeling;
- A traditional one-day household survey, a small subset of which were GPS-based, covering a total of 25,000 households;
- A two-week long-distance (over 50 miles) travel survey, covering 2000 households;
- TRANSEARCH data;
- A business establishment survey of about 800 establishments, supplementing the TRANSEARCH data;
- CTPP outside Ohio;
- Roadside surveys taken at approximately 700 locations;
- Other data sources, including traffic counts, travel time studies, etc.

On the supply side, a nested zoning system has been adopted (i.e. activity model zones, TAZs, and grid cells). The economic activity components have approximately 700 ‘activity model zones,’ each of which is made up of one or more TAZs from. The number of TAZs is 5103. For the purposes of maintaining land use and demographic data and for detailed microsimulation of personal and freight travel, each TAZ is further disaggregated into grid cells. In order to properly account for cross-border traffic, relatively larger TAZs have been created to cover a halo of around 50 miles into the surrounding states. All other US areas are represented by State-level zones.

The Ohio model used a great deal of traditional travel surveys, while Oregon has recently invested in a new Household Activity Survey, which has a more activity-based focus and should provide superior data.

4.3. Applications

The Ohio model was applied to analyze several tolling scenarios for the Turnpike Corridor. It has also been applied extensively in the State’s long-range transportation planning process. A ‘Macro Corridor’ system analysis used the Ohio model to identify highway routes which have high latent demand and therefore should receive priority funding (Giaimo and Schiffer 2005). It also contributed to the design and evaluation of the State’s Jobs and Progress Plan, which would invest new gas tax revenues to a series of transportation improvement strategies (Taft and Proctor 2003).

The Oregon model was used in a series of studies. The earliest TLUMIP model was applied in several local case studies: the Eugene-Springfield Area Case Study and the Willamette Valley Livability Forum Study, which both have tested the impact of various future land use, economic growth, vehicle mileage fees, highway
investment, and transit investment scenarios. It was also used in the Economic and Bridge Options Report study (Weidner et al. 2005). The model assessed the negative impact of bridges’ vehicle weight limit on State and regional economic production and jobs, transportation costs, and changes in travel and land use patterns, and helped making infrastructure investment decisions.

Two application examples of the Oregon model are discussed in greater detail below to showcase its capability in addressing various land use planning and policy issues.

The Oregon model was used in the Eugene-Springfield Case Study of UrbanSim, a metropolitan-scale urban and land use simulation system for integration with transportation models (Waddell 2002). UrbanSim was designed specifically to address the policy needs of metropolitan growth management and compare alternate scenarios, particularly emphasizing on the interactions between land use and transportation.

UrbanSim was designed with a completely disaggregate approach (Waddell et al. 2003) with seven model components, modeling individual households, jobs, and real estate development and location choices with 150-meter grid cells. In this case, the statewide model provided transportation system costs and other information to UrbanSim. With its microsimulation and integrated modeling structure, the Oregon model compatibly served as an external transportation model to derive travel access indicators, resulting in useful insights into the behavior of the UrbanSim model. This study also provided valuable information for future improvement to the land use component of the Oregon statewide model.

Another land use-related application was the Willamette Valley Livability Forum’s Alternative Transportation Futures Project (Oregon DOT 2001), which was also the first full application of the first-generation Oregon model. The statewide model was used to model eight transportation and land use scenarios:

- Reference Scenario
- Emphasis on Highway Investment
- Emphasis on Transit Investment
- Mileage Tax Emphasis (Travel Demand Management)
- Emphasis on Compact Land Use Development
- Hybrid 1 (a combination of the previous scenarios)
- Hybrid 2
- Hybrid 3.

The Oregon model was applied in two rounds in the scenario analysis, with the first round examining the first five scenarios and testing the responsiveness of land use and transportation patterns to various types of public policies. Results from the first round were used to develop effective hybrid scenarios. The second round then evaluated the proposed hybrid scenarios.

5. Observations on statewide model improvement plans

It is widely believed that the activity-based approach will inevitably replace the traditional four-step modeling approach (e.g. Virginia DOT 2009). The decision on whether and how to improve the statewide models based on traditional four-step
methods should be based on planning application needs. Several current statewide model improvement plans that gradually advance traditional four-step models toward richer behavioral representations are identified below, which should provide references and implications for decision-makers and modelers in other states.

In the California model, a completely disaggregate representation makes the model more sensitive to individual choices and, therefore, produces reasonable sensitivities to the new HSR proposal. Now California keeps updating its model to an integrated interregional transportation-land use-economic model (Caltrans 2009). The integrated model has the capability to better analyze the impact of policies, plans, programs, and major investments on transportation, the economy, and the environment.

In recent years, the New York Metropolitan Transportation Council (NYMTC) has pursued a tour-based model and planned to phase out the two original New Jersey models serving northern New Jersey (NJRTM and the New Jersey statewide model), though it is determined that the NYMTC model is not able to address some New Jersey statewide issues. In the end, New Jersey DOT has not immediately committed to replacing the current statewide model with the NYMTC tour-based model, because the new advanced model would take several years to complete. Instead, New Jersey DOT has focused on incrementally improving its existing statewide model.

Michigan decided to update its model to a tour-based version with a three-phase improvement program (Faussett 2005). The tour-based model structure at both urban and statewide levels was designed in the first phase, which also identifies data needs. The second phase conducted a tour-based statewide household travel survey. They are currently in the third phase utilizing the survey data to improve the statewide model.

Virginia and Indiana have both considered developing a more advanced statewide model. Their major concerns are the lack of experienced staff and the higher data requirements and costs. A recent Virginia DOT study shows that developing and maintaining an activity-based model is up to three times more expensive than an advanced four-step model over the course of five years (Virginia DOT 2009). The same study also found that activity-based modeling techniques will be inevitably required for certain statewide transportation analysis in Virginia. Therefore, the study recommends that Virginia should adopt a more incremental approach in improving its current statewide model toward a fully activity-based approach. Indiana recently incorporated a land consumption model with its statewide model (Ottensmann et al. 2009).

Following the success of the first-generation model, Oregon DOT has developed an ambitious plan to improve it and achieve a fully activity-based microsimulation structure. During the past decade, they have invested significant resources in the development of the Oregon2 statewide model and in a new Household Activity Survey. It is realized that delivering a production-version of a fully activity-based approach will take a long time and more resources than currently available. Subsequently, a Transitional Model is first developed to meet urgent transportation planning and policy analysis needs. Again, we observe an incremental statewide model improvement approach.

The Maryland State Highway Administration (SHA) has recently invested in the development of the Maryland Statewide Transportation Model (MSTM), which
provides a valuable tool for statewide transportation planning decision-making in Maryland. A working version of MSTM has been developed based on the traditional four-step method. Driven by planning analysis needs related to congestion management, pricing, multimodal freight analysis, and corridor-level integrated operations and planning analysis, SHA has already initiated a research project that will develop a phased model improvement plan toward advanced four-step and agent-based microsimulation models. A recent study tried to implement this improvement and integrated agent-based microsimulation in the corridor analysis of a new tolling facility in Maryland (Zhang et al. in press).

Based on these experiences, the incremental approach toward advanced four-step and activity-based models seems reasonable for most states aiming at advancing their statewide models. In addition, the incremental approach will also allow modeling staff to gradually master the new modeling techniques.

6. Conclusion

The traditional four-step approach is technically sound for statewide transportation modeling. It has proven successful in many states in a variety of transportation planning and policy analysis applications. Improvements to traditional four-step models can be costly and may take a long period of model development time and, therefore, should be pursued only if these improvements are necessary to address transportation planning and policy needs that are important for the states. However, experiences in several pioneering states suggest that some improvements on the basic four-step model are almost always needed for statewide applications. In particular, traditional four-step models have limited values in supporting decision-making with regard to HOV/HOT operations, dynamic tolling and congestion pricing, bus scheduling and service period extension, incident management, peak spreading, and corridor-level congestion management, multimodal freight modal shift analysis, and certain travel demand management strategies such as vehicle sharing programs and flexible work schedules.

Advanced four-step models could be cost-effective in enhancing certain aspects of the traditional four-step models, such as behavioral responses to congestion/pricing/new modes, multimodal freight analysis, and time-of-day considerations. Developing fully activity-based microsimulation models can significantly enhance statewide models’ capability in addressing modern transportation planning issues at the State level, such as congestion management, freight movement, sub-area/corridor traffic analysis, and integrated operations and planning analysis crossing MPO boundaries. They can cost a lot more (several times more) than traditional and advanced four-step models and take long development time. While several states (some already committed and some not yet committed to activity-based models) found the move to activity-based models would be inevitable in the future, all efforts in moving toward an activity-based paradigm have taken an incremental model improvement approach.

Several states have developed integrated transportation-land use-economic models at the state level. This broader statewide modeling scope has several appeals: (1) It allows two-way feedbacks between the transportation system and the land use/economic systems, which has many theoretical advantages; (2) It supports the analysis of integrated land use-transportation policies such as smart growth and
simultaneous transit investment; (3) It enables streamlined estimation of the impact of transportation improvement/investment on the State and regional economic growth and job creation. Despite these clear benefits, State should take a cautious approach in expanding their modeling scope to include land use and economic systems due to data availability and political realities.

Acknowledgements

This research has been supported financially by the Maryland State Highway Administration (SHA) under a project entitled Feasibility and Benefit of Advanced Four-Step and Activity-Based Travel Demand Models. The opinions in this paper do not necessarily reflect the official views of SHA and Maryland DOT. The authors wish to thank Morteza Tadayon, Subrat Mahapatra, Lisa Shemer, Allison Hardt, and Barbara Adkins for their valuable comments. The authors are solely responsible for all statements in this paper.

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